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THE PHYSICAL ASPECT OF GLASS-METAL SEALABILITY IN THE ELECTRONIC TUBE INDUSTRY

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By NORBERT J. KREIDL

PART I

Abstract

The outline of this extensive study is as follows:

Part I.

1. The Glass-Metal Seal from the Physical Viewpoint

2. Comparative Study of Test Methods

Part II.

3. Optimum Annealing Cycle of Glass

4. Optimum Annealing Cycle of Glass-Metal Seals

Part III.

5. Influence of Shape Variables Upon Strain

6. Influence of External Variables Upon Strain

7. Conclusions

The seals are defined and classified from functional, geometrical, and compositional viewpoints. The chemical aspects are not a subject of the study. The physical aspects are governed by the problem of heat treatment. The discussion is limited to the purely physical phenomenon of strain annealing. The physico-chemical aspect of structural annealing is eliminated. In the first part the behavior of glass is considered that of an elastic solid, relaxation phenomena in the annealing range are temporarily excluded, and the strain behavior is analyzed exclusively as a consequence of differential contractions below the annealing range. Only homogeneous metals are contemplated and flow is not assumed to take place in the temperature range considered.

In general, of course, permanent strain at ambient temperature is due to temperature gradients traversed in the annealing range of glass and to differential contraction of glass and metal in the annealing range, modified by relaxation, and below the annealing range, not so modified.

The final strain is considered influenced by the following intrinsic factors: expansivity of metal (linear, or of changing slope), expansivity of glass (always of changing slope), thermoviscous properties of glass, Young and Poisson coefficients of glass and metal, geometry of the seal, annealing and storing atmosphere, etc.

Test methods are set up to determine intrinsic properties and to anticipate strain patterns. The following methods are considered: strip fusion, absolute dilatometry, differential dilatometry, polarimetry.

As a polarimetric curve, the authors define the representative curve of the path difference of a sample of standardized geometry as a function of temperature in a standardized and automatically controlled cooling program starting at a point characterized by the standardized expansion curve of the glass—the annealing temperature. Differential, rather than absolute dilatometry is recommended for the purposes of sealing control and standardized on the alloy pyros having a mean expansion coefficient of 139.5 x 10^{-7}.

For the evaluation of polarometric data the relation of optical and elastic anisotropy is derived in detail. Two characteristic geometries (A, B) are selected for the purpose of simplified calculation (Fig. 1). The shape A permits easy evaluation of physical data but, because of the required immersion of the cylinder, is unsuited for the important polarimetric tests at elevated temperature. For this purpose sample B is suited.

In the case of the cylindrical seal A, the three principal strains (radial, tangential, and axial) were found as a function of the radial distance r and the following constants: E_2 (Young's module of glass), d (total differential contraction (α Metal—α Glass) (T-T_o)), the radii of glass and metal (a, b), the Poisson module taken constant at .3, the Young's module ratio (glass to metal) R. The values of the principal stresses, divided by $E_2 d$ (module of glass × differential contraction): $p_r/E_2/d$, $p_0/E_2 d$, $p_z/E_2 d$ were tabulated and graphically represented as functions of certain geometrical variables, leaving others constant.

Next, using an approximation proposed by Poritzky, the optical path difference was calculated using the Brewster coefficient and substituting the above variables and constants for the principal strains. In this way the expression $\delta/BE_2 d$ (path difference: Brewster coefficient × glass module × differential contraction) could be tabulated and graphically represented as a function of the above geometrical and intrinsic values.

Then, correspondence coefficients were derived linking maximum strains at the glass-metal interface and optical path differences observed. These coefficients, radial, tangential, and axial, are functions only of the metal diameter a and the module ratio $R = E_2$ (Young module of glass): E_1 (Young module of metal), and are tabulated and graphically represented.

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It is found that maximum strains are proportional to path differences, inversely proportional to Brewster coefficients and that the tangential and radial strains are by a factor depending upon the metal radius larger than the axial ones.

For samples B the strains themselves and the theoretical correlation of the path difference cannot be deduced. However, correspondence coefficients between maximum strains in three coordinates and the measured path difference could be derived, tabulated, and represented in the form of curves as functions of only a (metal radius) and R (module ratio). Again strains are proportional to path differences, inversely proportional to Brewster coefficients, and radial as well as tangential strains larger than axial strains by given factors depending upon the metal radius.

Accessory tests were the measurements of moduli. The temperature coefficient of the Young's modulus for metals was neglected, as was the variation of the glass module with temperature and imperfect annealing. The Poisson module was always assumed equal to .3. The Brewster constants are determined as a second accessory test. The variation of the Brewster coefficient with temperature and heat treatment was also neglected. All neglections caused maximum errors less than 10% and permitted the established curves to remain smooth and practical.

The application of tests is discussed as follows: The chief value of the dilatometric tests is the evaluation of the characteristic points of the glass. Otherwise the polarimetric tests give much smaller errors for the determination of final elongations. If the three constants, Young's module of glass and metal, and Brewster's constant of glass, are known, from the polarometric curve are derived: (a) The correspondence coefficients of maximum strain and path difference. (b) The path difference for A and B type samples of metal radius a. (c) The strain for all temperatures at which the seal may have to function. (d) From its slope, the slope of the strain temperature relation. (e) From its slope, for one radius—a_1—the relation of optical path difference and temperature for samples type B of other radii a_x by the simple proportion a_x-a_o/a_1-a_o, from a tabulation of a_o.

The only relation which cannot yet be obtained is that between ambient temperature strains of samples of two radii. This relation requires the knowledge of relaxation in the annealing range and will be treated in the next part of this study.

Introduction

In the technique of making electronic tubes, two basic problems can be distinguished (a) from the viewpoint of control, the determination of the strains caused by the use and the thermal treatment of a glass-metal pair in the realization of a seal of given shape and function; (b) from the viewpoint of construction, the determination of the intrinsic characteristics of the materials and the thermal treatment required for the realization of a seal of given shape and function.

These problems are confused by the great numbers of variables and the great difficulty of their separation and definition. Such variables are, for instance: The many physicochemical properties governing adherence; the diversity of the shapes and applications of seals; the strain limits which are tolerated in the various shapes, surfaces, atmospheric conditions, etc.

In many seals the magnitude and the distribution of strains cannot be established, except by the indirect evidence of birefringence.

The present discussion is limited to the physical aspects. Plant and laboratory experience is analyzed for the multiple purpose of establishing rationally: (1) Specifications of sealability permitting the control of materials received for sealing. (2) Specifications of annealing cycles for glass and glass-metal assemblies. (3) Specifications for the factory control of glass-metal sealing. (4) Specifications for new sealing materials.

THE PROBLEM OF GLASS-METAL SEALABILITY FROM THE PHYSICAL VIEWPOINT

Glass-Metal Seal in the Electronic Tube Industry

Definition.

In the electronic tube industry glass-metal seal means the intimate reunion of a mineral glass and a metallic material (pure metal or alloy), obtained generally by the fusion of the glass in contact with the metal.

Classification.

For the rapid examination of all current seals, Monack[1] has classified them according to (a) function of the metal part, (b) geometry of the seal, (c) type of glass.

(a) Metal function: (1) Lead of current; (2) Electrode support; (3) (1) + (2); (4) Electrode; (5) Window or Screen.

(b) Geometry: (See Fig. A and Fig. B.) (1) Internal Seal, (11) Wire, (12) Ribbon, (13) Tube; (2) External Seal, (21) Disc, (22) Plateau; (3) Tubular Seal, (31) Thin rim, (311) External, (312) Rider, (32) Rounded rim, (321) Internal, (322) External, (323) Rider; (4) End Seal, (41) Tubular, (42) Non-tubular; (5) Flat Seal; (6) Window Seal; (7) Composite Seal, (71) Eyelet, (72) Foot.

(c) Glass Type,

(1) Hard: Coefficient of expansion below 55 x 10^{-7}

(2) Soft: Coefficient of expansion above 55 x 10^{-7}

Desired Properties.

(a) Stability against perturbing influences such as: Continuous or discontinuous electrical tension at various frequencies, Temperature, Thermal Shock, Mechanical Shock, Electrical Shock, Atmospheric Attack.

(b) Economy, in units and in series.

Chemical Aspects of Glass-Metal Sealability

The chemical or physicochemical properties of the two materials condition, in part, the properties required of the seal, in particular glass-metal adherence.

This aspect is not the subject of this discussion and it is assumed throughout that the chemical or physicochemical properties permit convenient adherence.[1, 2]

Physical Aspects of Glass-Metal Sealability

Background.

The physical aspect of the problem is governed by the problem of heat treatment.

The discussion is limited to the purely physical aspect of annealing[3], i.e., annealing is identified as the treatment capable of attenuating strain which is considered the cause of the deficiencies of quenched glass and becomes manifest by a more or less accentuated birefringence.

The discussion eliminates the physicochemical aspect, that is the modification or arrangements of structural nature.[4, 5]

Therefore annealing of glass is to be defined as follows: *A piece of glass is annealed if it presents itself isotropic in polarized light.*

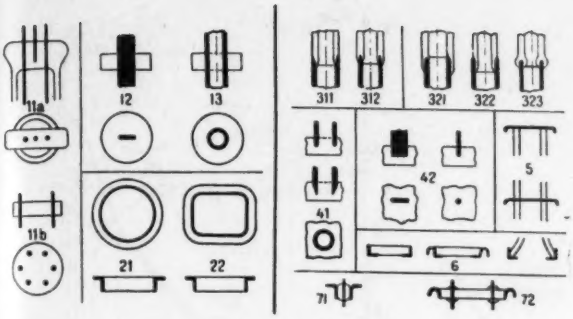


Fig. A and B.

The thermoviscous properties of glass are assumed known[3, 6] and reference is only made to the notions: Working Range, Transformation Range, Annealing Range.

The glass is considered to behave as a perfectly plastic solid (of low viscosity) at temperatures above the transformation range, as a perfectly elastic solid (of extremely high viscosity) at temperatures below the annealing range, and, finally as partially plastic, partially elastic in the transformation and annealing ranges.

Only homogeneous metals, presenting no relaxation or flow phenomena are considered in the given temperature ranges.

Strain. Origin of Strain.

During the Fashioning of the Seal. Strain Formation. The fashioning of a seal is effected at temperatures at which the glass is plastic enough to follow exactly the shape of the metal.

On Cooling: (a) Above the transformation range the glass executes all deformations imposed by the contraction of the metal without strain.

(b) In the transformation and annealing ranges the partially plastic, partially elastic glass develops strains because of the differential contraction of glass and metal, but part of the strain disappears because of the partial plasticity[4, 7]. On the other hand, permanent strain results from temperature gradients caused by too rapid cooling.*

(c) Below the annealing range the elastic glass follows elastically the deformations of the metal and permanent strains result from the differential contraction of the glass and the metal, presupposing perfect chemical adherence. Strains caused by thermal gradients appear but remain temporary.

Strains at Ambient Temperature. At ambient temperature, therefore, one finds in a glass-metal seal:

(a) Permanent strain due to temperature gradients traversed in the transformation and annealing ranges.

(b) Permanent strains due to differential contraction in the transformation and annealing ranges, modified by relaxation, and unmodified below the annealing range.

These strains can also be modified by the deterioration of adherence in the annealing and storing atmospheres.

A glass-metal seal is considered annealed if at ambient temperature permanent strains persist merely as a consequence of the differential contraction.

* Translator's Note: It would appear more consistent with recent experience to say that this permanent strain results from the partial disappearance of strain while the gradient has existed as described in the preceding sentence.

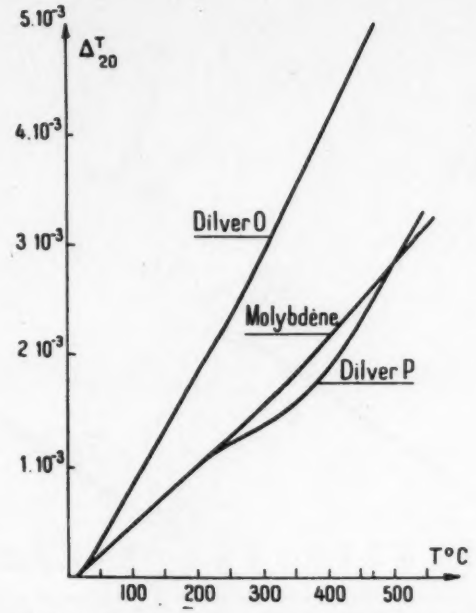


Fig. 1. Unit dilatation of metals and alloys as a function of temperature. Alloy Dilver O, Molybdenum, Dilver P.

During Use. The intensity and spatial distribution of strain may be modified in use: (a) Temporarily, i.e. by thermal shock or other events at temperatures below the annealing range. (b) Progressively, or permanently, i.e. by electrolysis, humidity, etc.

Factors Affecting Ambient Temperature Strain.

Intrinsic Variables of Materials. (a) The expansion curve of the metal. In practice, two large classes of metals may be distinguished.

aa. The expansion curve is sensibly linear in the domain of use. (Molybdenum and alloy Dilver-O in Fig. 1.)

bb. The expansion curve changes slope (Dilver-P, Fig. 1).

(b) The expansion curve and the thermoviscous properties of glass.[5, 6]

The difference of the expansions of glass and metal determine, in part, the elastic strains. The thermoviscous properties command totally, or in part, the factors of the annealing cycle: annealing temperature, duration of hold, cooling rate.

(c) The Young and Poisson coefficients of the materials.[7, 8]

According to Lane's theory these characteristics condition the amount of strain.

Variables of Shape. The dimensions and shapes intervene because in the elastic domain the intensity and spatial distribution are not only functions of intrinsic material variables but equally of the geometry of the seal.

These variables thus condition the annealing cycle in respect to: Duration of hold (relaxation time of strains as a function of their intensity); Relaxation of strains in the annealing range (as a function of their intensity); Cooling rate (thermal isotropy is more easily obtained in small pieces).

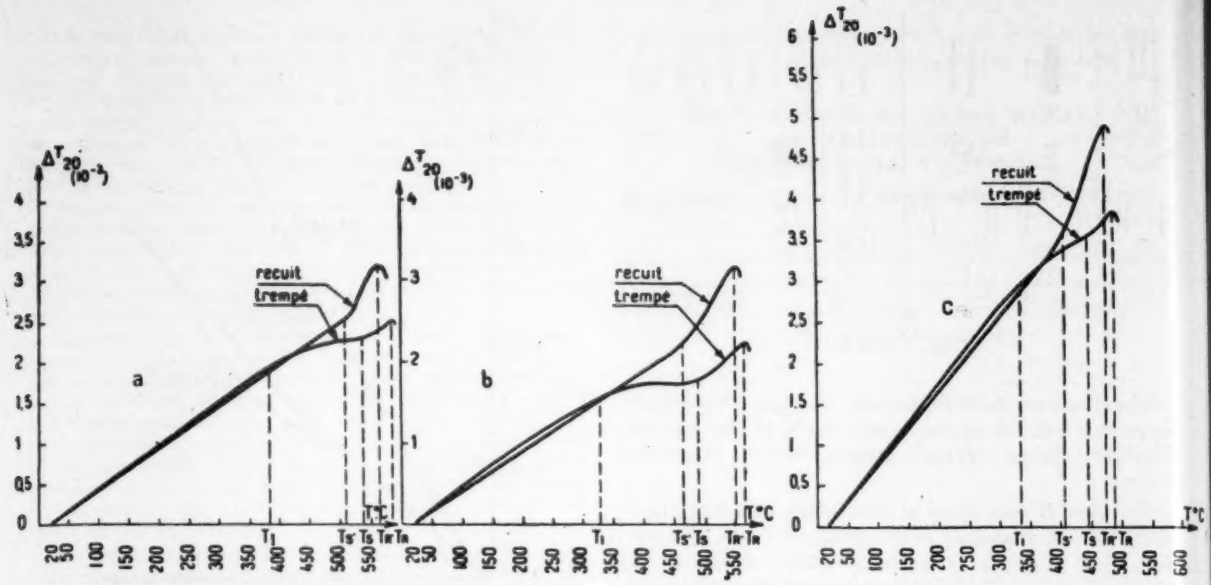


Fig. 2. Unit dilatation of glasses as a function of glasses as a function of temperature.

a. Glass A 119-1841 — quenched ("trempe"), annealed ("recuit")

b. Glass L 621 — quenched ("trempe"), annealed ("recuit")

c. Glass Televic 7.2.49 — quenched ("trempe"), annealed ("recuit")

External Variables. They are exemplified by the influence of the annealing and storing atmosphere which becomes manifest by a modification of intensity and spatial distribution of strains, e.g. in practice by the loosening of extremities.

COMPARATIVE STUDY OF TESTING METHODS

Strip Fusion of Glass

Violet[2] and Danzin[10] have described and specified the glass test called "strip fusion".

This test permits to follow the fluctuations of the expansion of glass with great sensitivity. Excellent results cannot be expected if the families of the glasses compared are too different (—different thermoviscous properties).

Dilatometric Effects

Since dilatometric tests are classical, the discussion is

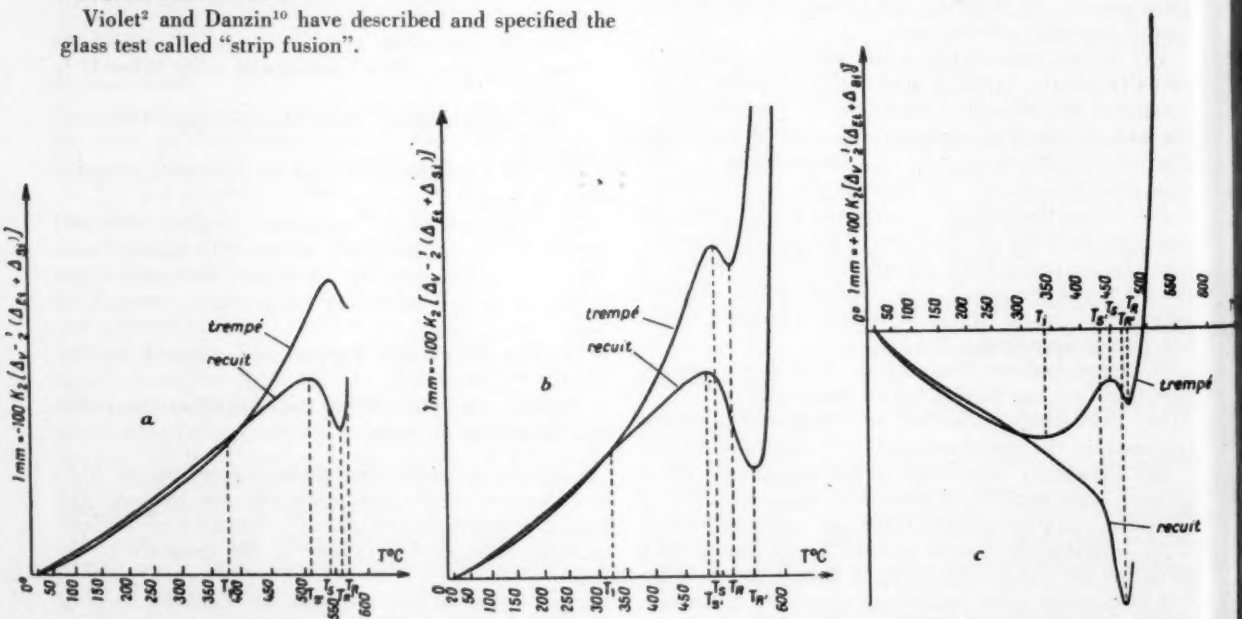


Fig. 3. Differential dilatometric curves (standard alloy pyros = 139.10^{-7}) obtained with the Chevenard. (glass sample 100 mm, pyros 50 mm long.) Magnification y : 131, y : 285.7. Further reduced 2/3 for print.

a. Glass A 119-1841 — quenched ("trempe"), annealed ("recuit")

b. Glass L 621 — quenched ("trempe"), annealed ("recuit")

c. Glass Televic 7.2.49 — quenched ("trempe"), annealed ("recuit")

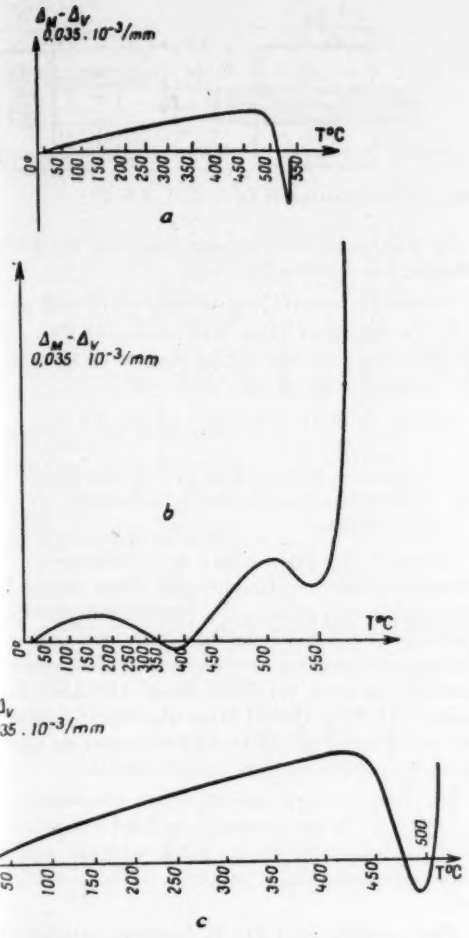


Fig. 4. Differential dilatometer curves obtained with the Chevenard. Magnific. as on Fig. 3.

a. Glass A 119-1841 — annealed
b. Glass L 621 — annealed
c. Glass Televic 7.2.49 — annealed

imited to what one may obtain from them.

"Absolute" Dilatometry. (e.g. Pellin instrument.)

This procedure is not used in the laboratory of the riters. What one may obtain from the test—given the xpansion of silica—is:

The true expansion curve of the materials between 0°C. and T°C. (Fig. 1 and 2.)

The expansion coefficients. The mean coefficient, for lasses usually between 20 and 300°C. The true coefficient, at T°C., from the slope at T°C.

The characteristic temperatures of materials.[3, 6] The ransformation temperatures are: (Fig 1, 2)

T_I Lower annealing (quenching) temperature

T_S Upper annealing temperature of the annealed glass

$T_{S'}$ Upper annealing temperature of the quenched glass

T_R Dilatometric softening point

Differential Dilatometry. (Chevenard)

Differential dilatometry was utilized in the laboratory

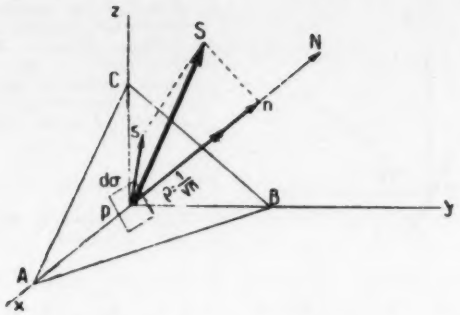


Fig. 5. Definition of strain S relative to surface element dσ in point P of a strained elastic solid.

of the writers using as a standard: *Standard: Alloy Pyros.* $\alpha = 139.5 \times 10^{-7}$ or (Examples Fig. 3). *Standard: The Metal to Which the Glass Is To Be Fused,* (Examples Fig. 4).

Remarks On Dilatometric Tests.

(a) Whatever apparatus is used, identical conditions must be maintained to warrant comparable results.

(b) The characteristic temperatures are more easily obtained by differential dilatometry. ($\mp$ 5°C. on quenched rods 100 or 50 mm long).

Polarimetry

Background. Strain and Birefringence.[8]

In a point P, belonging to an elastic body subject to Hooke's law and subjected to a system of forces, elastic forces appear which, in equilibrium, are compensated by strains of equal magnitude and opposite sign. These strains, the origin of which is described for glass-metal seals in the present papers, give rise in glass to the birefringence upon which are based the polarimetric tests.

In point P (Fig. 5) strain S relative to the surface element dσ with the normal N is defined as the limit value of strains across the triangle ABC with the normal N as it approaches infinitesimally point P, a convention with regard to N defining positive and negative (compression and tension) strains.

The total strain S can be decomposed in normal (n) and tangential (s) strains.

The locus of all extremities of vectors $\frac{1}{\sqrt{n}}$ along the normal N if dσ occupies all directions around P is a Cauchy solid formed from two hyperboloids of equal asymptotic cones if both compression and tension exist about P, and degenerates into an ellipsoid if there exists only either compression or tension at P.

From the Cauchy solid one determines: The nature of the strain, extension or compression; The magnitude in the normal — n; The direction of the total strain; The magnitude of the total strain.

The axes of the Cauchy solid are called principal and for elements dσ normal to these axes strains are purely normal and called principal strains which completely define the strain system of P.

The locus of all summits of total strain vectors S, if dσ has all directions around P, is the so-called elasticity

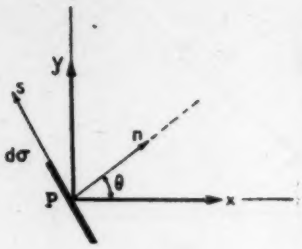
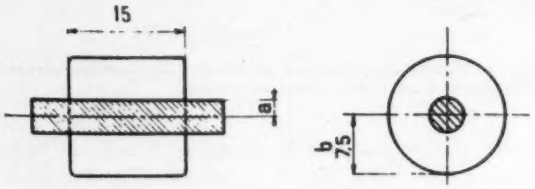


Fig. 6. Left, Normal and tangential strains at a surface element dσ as functions of the principal strains in point P of a solid subject to a system of plane strains.

Fig. 7. Below, Sample type A (a = .5, 1, 1.5, 2)



ellipsoid of Lame. Its axes are identical with that of the Cauchy curve and the half lengths represent the magnitudes of the three principal strains.

The electromagnetic theory of light teaches that in the point P of an anisotropic medium—and that is what glass under strain is—the optical indices vary in the so-called index ellipsoid the axes of which coincide with those of the Lame ellipsoid and the Cauchy solid. The indices along the principal axes are called principal indices.

Neumann and Maxwell have established the relation between the principal indices and the principal strains in a point P.

$$N_x - n = C_1 x + C_1 (y + z)$$
$$N_y - n = C_1 y + C_2 (x + z)$$
$$N_z - n = C_1 z + C_2 (x + y)$$

where n = ordinary index

$N_x\, N_y\, N_z$ = principal indices

x y z = principal strains

$C_1\, C_2$ = principal photoelastic coefficients

The path difference of two rays emerging from P is given by: $\delta = (N' - N'')\, de$

Here N′ N″ are the indices corresponding to the half axes of the ellipse formed by the intersection of the index ellipsoid in P by the wave plane of the incident ray. These indices N′, N″ are called principal in the wave plane.

This general case was discussed because it permits treatment of the problem in question. From it all particular cases can be derived.

Case (a). y = z = o. The incident ray is vertical to x,y.

$$N_x - n = C_1 x$$
$$N_y - n = N_z - n = C_2 x$$
$$\delta = (N' - N'')\, de = (C_1 - C_2\, x\, de = B\, x\, de)$$

Case (b). z = o. The incident ray is vertical to x,y.

$$N_x - n = C_1 x + C_2 y$$
$$N_y - n = C_1 y + C_2 x$$
$$N_z - n = C_2 (x + y)$$
$$\delta = (N' - N'')\, de = (N_x - N_y)\, de =$$
$$(C_1 - C_2)\, (x - y)\, de = B\, (x - y)\, de$$

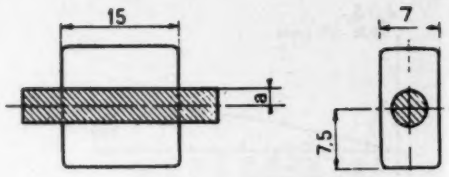


Fig. 8. Sample type B (a = .5, 1, 1.5, 2)

In both cases (a) (b) one finds that the Brewster coefficient B is equal to $C_1 - C_2$.

It remains to make one remark which will serve later:

For a system of plane strains around P(z = o) (Fig. 6) the values of the strains tangential (s) and normal (n) to the element dσ are:

$$n = \tfrac{1}{2}\,(x + y) + \tfrac{1}{2}\,(x - y)\cos 2\theta =$$
$$x \cos^2\theta + y \sin^2\theta$$
$$s = \tfrac{1}{2}\,(x - y) \sin 2\theta = (x - y) \sin\theta \cos\theta$$

Test Samples.

Test samples must satisfy two conditions: (a) They should be easily realizable. (b) They should be easily measurable cold or hot. (c) They should allow the establishment of a relation between measured path difference and the actual effect of variations in the sample such as intrinsic material variables, shape variables, heat treatment. (d) They should allow the establishment of a relation between path differences measured on them and on real pièces made from the same materials.

The simplest form would be the cylindrical assembly A of Fig. 7. It can be easily realized but must be measured by immersion in an index medium and does not allow measurements of strain as a function of temperature.

The assembly B of Fig. 8, however, satisfies all above conditions.

The Relation of Path Difference and Strain.

The relation between the path difference measured and the strain in seals of the A and B type are to be considered simply in which glass can be considered all elastic solid, that is under elimination, for the present, of the relaxation phenomenon.

In this case one can obtain a relation between the path difference, the intrinsic characteristics of the material and the shape of the test sample, all for a given heat treatment.

The effects of heat treatment and relaxation are to be treated in Part 2.

Samples of Type A. Distribution of Strains.[7, 9]

Poritzky has established that everywhere in the glass of a cylindrical seal exist three principal effects (Fig. 9)

p_r : radial

p_θ : tangential

p_z : axial

Starting from Poritzky's fundamental equations, Hetenyi and Burger have calculated p_r p_θ p_z in the case of an indefinite cylindrical assembly of vertical cross section (convention of sign: + = compression, — = tension)

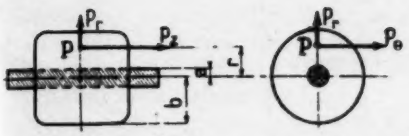


Fig. 9. Principal strains in sample A according to Poritzky, Hull and Burger.

$$p_r = -\frac{E_2 d}{1+\alpha+\alpha\beta R}\left(\frac{a^2}{b^2}-\frac{a^2}{r^2}\right)$$

$$p_\theta = -\frac{E_2 d}{1+\alpha+\alpha\beta R}\left(\frac{a^2}{b^2}+\frac{a^2}{r^2}\right)$$

$$p_z = -\frac{E_2 d}{1+\alpha+\alpha\beta R}\left(2\sigma\frac{a^2}{b^2}+\frac{1+\alpha+\alpha\beta R}{1+\beta R}\right)$$

a = radius of the metal part

b = radius of the glass part

r = radial distance of point under consideration

E_1 = Young module of metal

E_2 = Young module of glass

σ = Poisson module, taken equally at .3

$R = E_2/E_1$

$$\alpha = \frac{a^2}{b^2}(1-2\sigma) \qquad \beta = \frac{b^2}{a^2}-1$$

$d = (\alpha \text{ metal} - \alpha \text{ glass})\ (T - T_o)$

α metal, glass = mean coefficients of expansion between T_o and T°C.

The sign of d is given in the following table:

	$T > T_o$	$T < T_o$
α Metal $>$ α glass	+	−
α Metal $<$ α glass	−	+

We give the variations of

$$-\frac{p_r}{E_2 d}, \quad \frac{p_\theta}{E_2 d} \text{ and } \frac{p_z}{E_2 d}$$

for $R = E_2/E_1 = .25;\ .33;\ .5;\ 1.$

as a function of b/a for r = a (Fig. 10)

Table 2

Samples type A. (cylindrical)
Theoretical values of $p_r/E_2 d$, $p_\theta/E_2 d$, $p_z/E_2 d$ as functions of a (metal radius) and r (distance) for b (glass radius) = 7.5, R (module ratio) = .25, .33, .5, 1. and d<0 (contraction).

$b = 7.5$			$r = a$			$r = b = 7.5$			
a	b/a	R	$\left(\frac{p_r}{E_2 d}\right)$ max.	$-\left(\frac{p_\theta}{E_2 d}\right)$ max.	$-\left(\frac{p_z}{E_2 d}\right)$	$\left(\frac{p_r}{E_2 d}\right)$	$-\left(\frac{p_\theta}{E_2 d}\right)$	$\left(\frac{p_r}{E_2 d}\right)$	$-\left(\frac{p_\theta}{E_2 d}\right)$
		1	0.715	0.715	0				
		0.50	0.834	0.834	0				
→0	→∞	0.33	0.882	0.882	0				
		0.25	0.910	0.910	0				
						$r = 2$			
		1	0.710	0.714	0.0063	0.0415	0.0478	0	0.0063
		0.50	0.830	0.840	0.011	—	—		—
0.5	15	0.33	0.875	0.835	0.015	—	—		—
		0.25	0.900	0.910	0.020	0.061	0.0526	0	0.0080
						$r = 2.5$			
		1	0.700	0.730	0.025	0.101	0.127	0	0.0254
		0.50	0.816	0.850	0.044	—	—		—
1	7.5	0.33	0.865	0.895	0.061	—	—		—
		0.25	0.886	0.925	0.076	0.129	0.162	0	0.0324
						$r = 3$			
		1	0.685	0.742	0.057	0.150	0.207	0	0.0570
		0.50	0.795	0.860	0.097	—	—		—
1.5	5	0.33	0.840	0.905	0.132	—	—		—
		0.25	0.865	0.935	0.164	0.191	0.264	0	0.0726
						$r = 3.5$			
		1	0.665	0.765	0.100	0.182	0.284	0	0.1010
		0.50	0.765	0.880	0.167	—	—		—
2	3.75	0.33	0.805	0.925	0.214	—	—		—
		0.25	0.830	0.960	0.272	0.232	0.360	0	0.1290
		1	0.535	0.896	0.357				
		0.50	0.600	1.000	0.520				
3.75	2	0.33	0.625	1.040	0.625				
		0.25	0.637	1.060	0.700				
		1	0.396	1.030	0.710				
		0.50	0.430	1.120	0.821				
5	1.5	0.33	0.442	1.150	0.917				
		0.25	0.450	1.165	0.975				
7.5	1	any	0	1.430	1.430				

of a for $\tau = a$, $b = 7.5$ (Fig. 11)

and of r for $a = .5$, $b = 7.5$ (Fig. 12)

$= 1.$

$= 1.5.$

$= 2.$

The corresponding numerical values are given in Table 2.

It should be noted that in practice the influence of $R = E_2/E_1$ cannot be neglected.

Calculation of Path Difference. (a) Application of Index Formula. It has been shown that for a system of non plane strains for the determination in a point P of the path difference between two emerging extraordinary rays one has to know for this point the index values corresponding to the axis of the ellipse of intersection between the index ellipsoid and the wave plane of the incident ray (the principal indices in the wave plane). Consider in Fig. 13, the ray AB perpendicular to the sample axis.

At the point P_1, the path difference between the two emerging extraordinary rays will be:

$$\delta = (N_z - N'')\, de$$

N_z and N'' are, in P_1, the indices corresponding to the axes of the ellipse of intersection (trace in (E)) of the ellipsoid of indices (Σ) with the wave plane of ray AB.

At the Point P_2, symmetric to P_1, in rapport to YY'

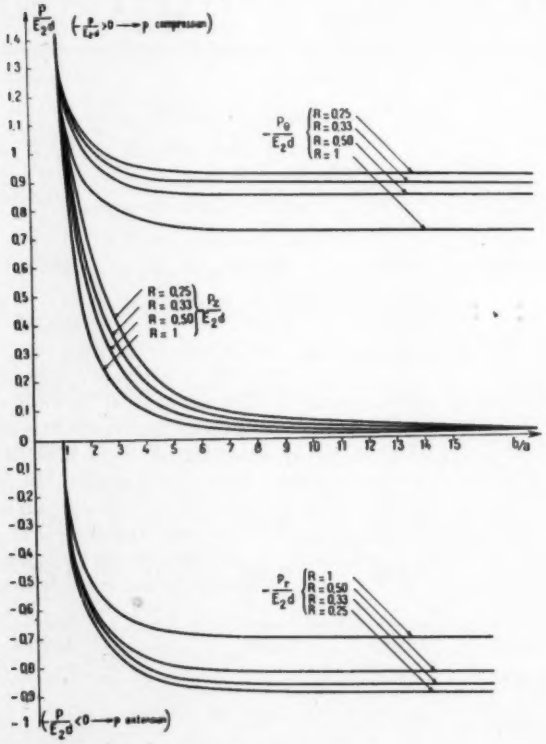


Fig. 10. Sample type A. Theoretical values of:
p_r/E_2d, p_θ/E_2d, p_z/E_2d (strains : module X contraction) as functions of b/a (glass radius : metal radius) for $r = a$, $b = 7.5$; $d<0$ (contraction)
E_2 and P in kg/mm²; d in mm/mm
Positive P compression, negative P tension.
Curves labelled for $R = E_2/E_1$ = Young module ratio glass metal.

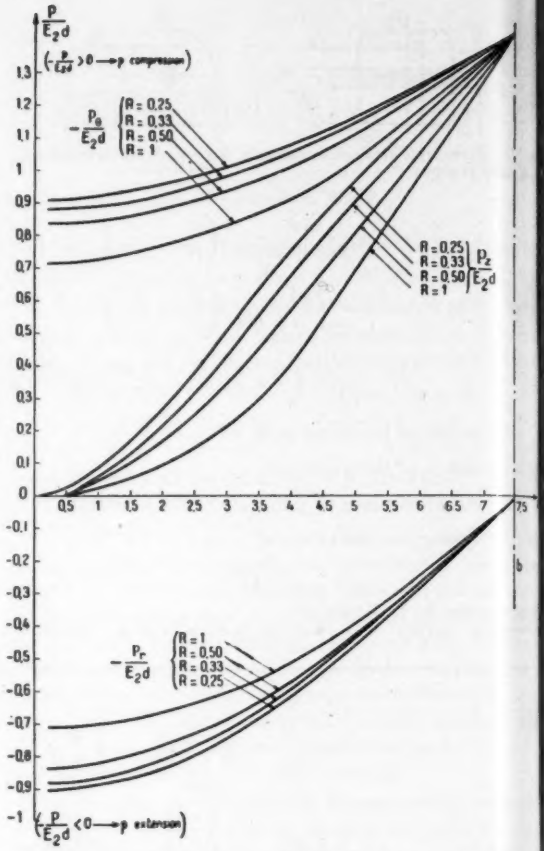


Fig. 11. As Fig. 10, however, P/E_2d values as functions of the metal radius a.

one has the same index ellipsoid (Σ) as in P_1, and the same ellipse of intersection (E) with the wave plane in P_2 thus the difference of the elementary path will also be:

$$\delta = (N_z - N'')\, de$$

The two symmetrical elements de therefore behave like two juxtaposed crystal lames of equal extraordinary indices and parallel axes. The total path difference from A to B thus becomes:

$$\delta = 2\int_0^{e_1} (N_z - N'')\, de$$

$$= 2\int_0^{e_1} \left(N_z - \frac{N_o N_r}{\sqrt{N_o^2 \sin^2\theta + N_{r2} \cos^2\theta}} \right) de$$

The Maxwell formula permits expressing N_r N_θ N_z as functions of the principal strains, the ordinary index, and the absolute photoelectric constants C_1 and C_2; and, δ can be calculated.

(b) *The Approximation of Poritzky.* The application of the preceding formula leads to the exact relation between the path difference and the intrinsic characteristics of the seal, in terms, however, of n, C_1, C_2, which are more difficult to determine in the industrial laboratory than the Brewster coefficient B.

Therefore, the strain system in P is now treated, in

approximate fashion proposed by Poritzky[9], as a system of plane strains. In this case (See Polarimetry Background) the strain on the light ray AB is the tangential strain P on the thickness element de:

$$p = p_\theta \cos^2\theta + p_r \sin^2\theta \text{ (Fig. 14)}$$

In this case the path difference becomes:

$$\delta = 2B\int_0^{e_1} (p_z - p)\, de$$

and taking the Hull-Burger expressions for $p_r p_\theta p_z$, in which $r = a/\sin\theta$, and making:

$$k_1 = -\frac{1}{1+\alpha+\alpha\beta R}$$

$$k_2 = \frac{1+\alpha+\alpha\beta R}{1+\beta R}$$

one obtains:

$$p_r/E_2 d = k_1\left(\frac{a^2}{b_2} - \sin^2\theta\right)$$

$$p_\theta/E_2 d = k_1\left(\frac{a^2}{b^2} - \sin^2\theta\right)$$

$$p_z/E_2 d = k_1\left(2\sigma\frac{a^2}{b^2} + k_2\right)$$

and:

$$\delta = 2Ba\left(\int_{\theta o}^{\pi/2} p_z \frac{d\theta}{\sin^2\theta} + \int_{\theta o}^{\pi/2} (p_\theta \cos^2\theta + p_r \sin^2\theta)\left(\frac{d\theta}{\sin^2\theta}\right)\right.$$

$$\theta = \arctan\frac{a}{e} \qquad \theta_o = \arcsin\frac{a}{b}$$

At the conclusion of all calculations one finds:

$$\int_0^{e_1} -p\,de = a\int_{\theta_o}^{\pi/2} (p_\theta \cos^2\theta + p_r \sin^2\theta)\frac{d\theta}{\sin^2\theta} = 0$$

Thus the path difference remains a function only of a, and:

$$\delta = 2B\int_0^{e_1} p_z\,de = 2Ba\int_{\theta o}^{\pi/2} p_z \frac{d\theta}{\sin^2\theta}$$

$$\delta/BE_2 d\,a = (k_1)\left(2\sigma\frac{a^2}{b^2} + (k_2)\right)\int_{\theta o}^{\pi/2}\frac{d\theta}{\sin^2\theta}$$

$$\delta/BE_2 d = 2a(k_1)\left(2\sigma\frac{a^2}{b^2} + (k_2)\right)\sqrt{\frac{b^2-a^2}{a}}$$

explicitly:

$$\delta/BE_2 d = \frac{2}{-1+\alpha+\alpha\beta R}\left(2\sigma\frac{a^2}{b^2} + \frac{1+\alpha+\alpha\beta R}{1+\beta R}\right)\sqrt{b^2-a^2}$$

The numerical results are given in Table 3 and graphically, Fig. 15.

Path Differences For Maximum Strain. In the sample type A strain maxima are always located at the metal interface (Fig. 12).

If one knows, on the one hand:

$$(p_r/E_2 d)\max (p_\theta/E_2 d)\max p_z/E_2 d = f(a, R)$$

And, on the other hand:

$$\delta/BE_2 d = \Phi(a, R)$$

One can define correspondence coefficients for maximum strain path differences k_r, k_θ, k_z so that:

$$(p_r)\ \max = k_r\,\delta/B$$
$$(p_\theta)\ \max = k_\theta\,\delta/B$$
$$p_z = k_z\,\delta/B$$

These coefficients are functions only of a and R. The values of k_r, k_θ, k_z are given in Table 3. For $.5<a<2$ these coefficients are:

(1) Practically (by $\mp$ 7%) equal for p_θ, p_r.

(2) Practically independent (by $\mp$ 4%) from a, R, for p_z.

Table 3

Sample type A. (cylindrical seal)

a. Values of $\delta/BE_2 d$ (path difference : Brewster's coefficient X glass module X contraction) as functions of a (metal radius) according to Poritzky's approximation, for the cases:

Module	**b = 7.5**
Ratio	**R = .25, .33, .5, 1.**
	d < 0 (contraction).

b. Values of correspondence coefficients k_r k_θ k_z between maximum strains and path differences.

a	R	$\frac{-\delta}{BE_2 d}$ Poritzsky	Hull Burger	$-k_r$	k_θ	k_z	$-k_r = k_\theta$ moyens	k_z moyen
	1	0.094		7.55	7.60	0.067	7.57	
	0.50	0.165		5.00	5.10	0.067	5.05	
0.5	0.33	0.232		3.78	3.80	0.065	3.79	0.067
	0.25	0.264		3.40	3.45	0.076	3.42	
	1	0.385		1.82	1.90	0.065	1.86	
	0.50	0.650		1.25	1.30	0.0675	1.27	
1	0.33	0.925		0.935	0.97	0.066	0.95	id.
	0.25	1.17		0.760	0.79	0.065	0.77	
	1	0.84		0.815	0.885	0.068	0.85	
	0.50	1.38		0.575	0.625	0.070	0.60	
1.5	0.33	1.94		0.435	0.465	0.064	0.45	id.
	0.25	2.43		0.356	0.385	0.0675	0.37	
	1	1.48		0.450	0.515	0.0675	0.48	
	0.50	2.43		0.315	0.360	0.067	0.34	
2	0.33	3.25		0.248	0.285	0.066	0.27	id.
	0.25	3.95		0.210	0.242	0.0685	0.225	
	1	4.43						
	0.50	6.50						
3.75	0.33	7.80						
	0.25	8.90						
	1	7.20						
	0.50	9.35						
5	0.33	10.60						
	0.25	11.60						
	1	8.25						
	0.50	9.65						
6	0.33	10.30						
	0.25	10.60						
7.4	quel-	3.7						
7.5	conque	0						

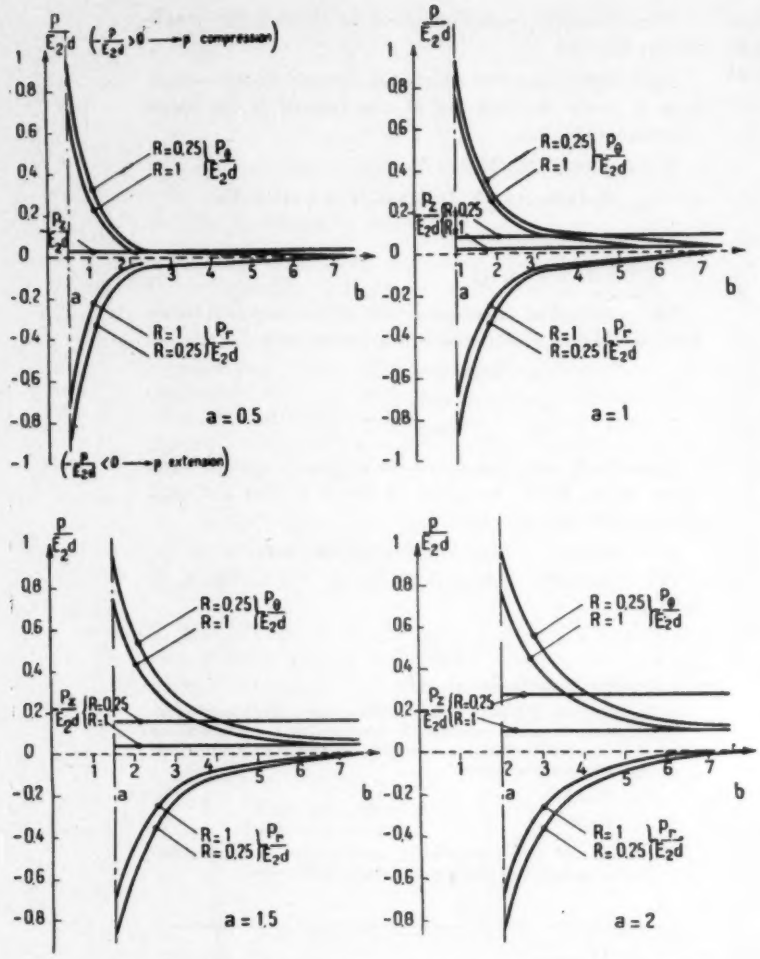


Fig. 12. As Fig 10, however, P/E₂d values as functions of the radial distance r.
b (glass radius) = 7.5, a (metal radius) = .5, 1, 1.5, 2.

One may retain but the mean values given in Table 3 and represented graphically in Fig. 16 as functions of a and R.

It should be noted that:

(1) Maximum strains are proportional to δ

(2) Maximum strains are inversely proportional to B.

(3) To small path differences δ correspond small values of p_z, but greater values for p_r, p_θ, e.g.:
$p_\theta\ p_z \sim 7$ (for a = 2); ~ 100 (for a = .5).

Samples of Type B (See Fig. 17). The distribution of strains in samples type B cannot be predicted. It is, therefore, impossible to establish a theoretical correlation of path differences and maximum strains at the metal contact.

Experimental Apparatus.

The apparatus used (Fig. 18) is conventional. Therefore, a summary description will suffice. The polarizer is a Malus mirror operating at the Brewster angle, the analyzer a nicol. Polarizer and analyzer are crossed.

Between them is placed a wave plate for yellow radiation. If the incident light is "white", the color in the analyzer is called "sensible".

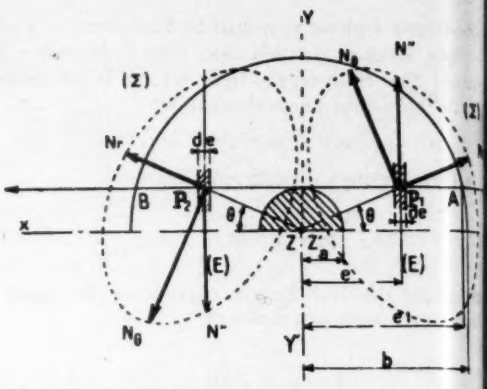


Fig. 13. Sample type A. Determination of birefr along a ray perpendicular to the axis and tangenti metal from the index formula.

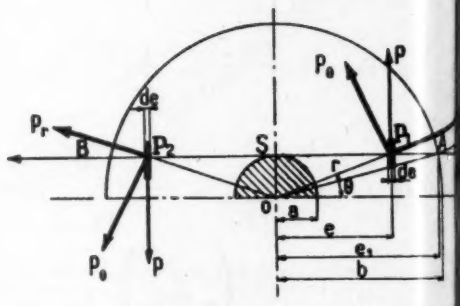


Fig. 14. Sample type A. As figure B, but approxi termination, according to Poritzky.

Between polarizer and the wave plate of "sensib color is another wave plate the traversed thickness which can be varied by inclination around an axis to the polarization plan: that is the compensator sta ardized for yellow light. It permits reestablishing "sensible" color when it has disappeared as the con quence of the interposition of the sample between pol izer and compensator. The angle of rotation of the co pensator permits the determination of the compensa path difference which equals the path difference int duced by the sample.

The Polarimetric Curves.

Using the described polarimeter, the path differen caused by a sample type B can be measured between two extraordinary rays deriving from an incident perpendicular to the large faces, grazing the metal situated in the symmetry plane vertical to the axis to avoid end effects). This determination can be m at all temperatures by putting the sample between pol izer and compensator in a convenient furnace.

The axis of the sample is placed at 45°C. ($\mp$) to plane of polarization so that the components of the cident ray following the axis of the sample and an perpendicular to it are of equal intensity.

By comparison with a strain of known sign and obs

(*Continued on page*

A PREVIEW OF THE A.C.S. MEETING IN CHICAGO

The Fifty-Third Annual Meeting of the American Ceramic Society will get underway on Sunday, April 22, at the Palmer House in Chicago.

The various divisions of the Society will hold their meetings from Monday, the 23rd, through Wednesday, the 25th. During this period, a new Division, recently authorized by the Board of Trustees and known as the Basic Science Division, will hold its meetings. Thursday, the last day of the Annual Meeting, will be devoted to plant trips.

The usual pattern of the Meeting will be followed this year with the General Session leading off on Monday morning. There will be two speakers at this session—William C. Taylor, Vice President and Director of Manufacturing and Engineering of Corning Glass Works, and Hewitt Wilson, Director of the Southeastern Region, Bureau of Mines. Dr. Taylor will deliver the 1951 Edward Orton, Jr. Fellow lecture. Mr. Wilson's topic will be "New Minerals for Ceramics".

Presiding over the general session will be J. W. Heplewhite, President of the Society. Howard R. Lillie, President-Elect, will head the new officers to be installed. Ralph K. Hursh, Emeritus Member of the American Ceramic Society and now a member of the Faculty of the University of Illinois, will be the recipient of the third annual Ross Coffin Purdy Award. This award is made for "the most valuable contribution to ceramic literature".

According to advice from the Society, more than one hundred and thirty-five papers have been scheduled for presentation at the sessions of the eight divisions. During the five technical sessions of the Glass Division, eighteen papers will be presented on glass technology. In addition to these papers, glassmen will find interest in some of the papers to be presented at the Refractories Division which will deal specifically with glass tank refractories.

Those attending the meeting will find in the *Bulletin* of the American Ceramic Society the detailed daily program of events and chronological presentation of the papers to be presented at the various division meetings. However, a review of the Glass Division's activities, as far as technical papers are concerned, follows.

Howard R. Lillie will present a paper dealing with a method for measuring the flow point of glass. In this paper, an apparatus and procedure are described for tests which will indicate the temperature at which a glass attains a substantial fixed viscosity level.

A method for determining Young's Modulus of glass at elevated temperatures will be presented by D. A. McGraw of Owens-Illinois Glass Company. Described in this paper is a means for the measurement of Young's Modulus of soda-lime-silica glasses at temperatures ranging up to 1250° to 1300°F.

A modification of Bunsen's ice calorimeter for measuring specific heats of glasses will be described by J. R. Johnson of the University of Texas.

L. C. Hoffman and W. A. Weyl of Pennsylvania State College are the authors of a paper on low temperature viscosity glasses. The paper, to be presented by Mr. Hoffman, will supply data on low temperature viscosities of simple glasses as an aid to a better understanding of composition-viscosity relationships.

The result of some of the work carried on at the National Bureau of Standards is evidenced by a paper to be delivered by Leo Shartsis on the density and viscosity of binary alkali silicates. In this paper, Mr. Shartsis will present the results of a study of viscosities and densities of melts in the systems Li_2O-SiO_2 and K_2O-SiO_2.

Dr. Alexander Silverman, Head of the Department of Chemistry of the University of Pittsburgh, will discuss the chemical durability of glass. In his paper, Dr. Silverman will touch upon what we might find helpful in a study of ancient glass and will list a variety of durability problems with which the glass industry is currently confronted.

Tests of surface durability of glass is a subject with which Harold E. Simpson, New York State College of Ceramics, is familiar (see Some Tests of Surface Durability of Bottle Glass, THE GLASS INDUSTRY, November 1950). In the paper which he will present to the Glass Division, Dr. Simpson will discuss some of the factors involved in the testing of surface durability in which flat glass was studied.

Another discussion on the subject of the surface of sheet glass will be made available by F. L. Bishop of the American Window Glass Company. In his paper, Mr. Bishop will discuss the surface of sheet glass as compared with the interior, and will present some measurements on the results of weathering.

J. V. Fitzgerald of Pittsburgh Plate Glass Company at Creighton, Pa., will offer a paper on the anelasticity of glass. Mr. Fitzgerald holds that glass in its various relaxation processes is imperfectly elastic or anelastic. He suggests, therefore, that in the light of Zener's theory, anelasticity, now a valuable tool in metal-

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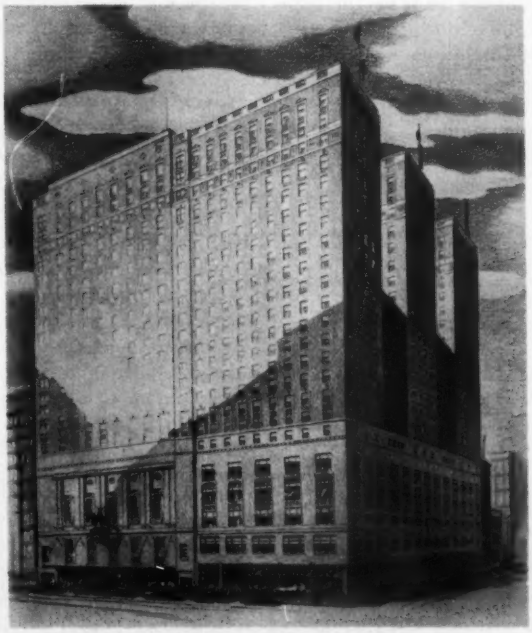

The Palmer House, Convention Headquarters

NEW GLASS ANNEALING LEHR PROVIDES SPACE AND FUE ECONOMIES

By ROBERT P. CASSELL, Chief Engineer

The Jeannette Glass Company, Jeannette, Pa.

For the past year, the Jeannette Glass Company has been investigating a new concept in glass plant annealing operations. Faced with limited floor space in our existing buildings, we have been exploring the possibilities of using the overhead space in our present plant more effectively.

The Transvertical Lehr

Most glass annealing operations are based on the idea that the annealing process is essentially one of subjecting the glass to a time-temperature curve. Time is usually controlled as a linear function—that is, the length of the furnace—in most modern continuous annealing lehrs. This length factor also helps to attain the desired capacity in the lehr. The distance is usually thought of as a straight line in most furnace engineering—in the metal-working industry's heat treating furnaces as well as the glass industry's annealing lehrs. There is no apparent reason why this distance could not be employed just as effectively if it were folded up in the manner of a carpenter's rule, with the total required distance, and, hence, furnace time being attained as the sum of the various horizontal and vertical legs. Such a lehr would make use of overhead as well as floor space.

A new lehr, embodying just this concept, was designed and constructed by Surface Combustion Corporation, of Toledo, Ohio. This firm, which has constructed hundreds of glass annealing lehrs of the conventional tunnel type, has built a new multiple layer conveyor lehr and designated it the "Transvertical Lehr". For convenient reference, this name will be used in the balance of this article. The lehr was installed in the plant of The Jeannette Glass Company in early 1950 and exploratory work to determine its applications and limitations was initiated.

The development activities have been concentrated particularly in the control of the heating curve and the simplification of the conveyor mechanism. We now believe that the Transvertical Lehr is a proved and wo ing tool for the glass industry. The lehr is capable performing annealing operations which formerly quired a floor space of 10 or 11 ft. by 120 ft. or 12 sq. ft. in a space of 10 ft. by 32 ft. or 320 sq. ft. T has meant real economies to us since it provides the ba for further expansion within the confines of our pres plant area.

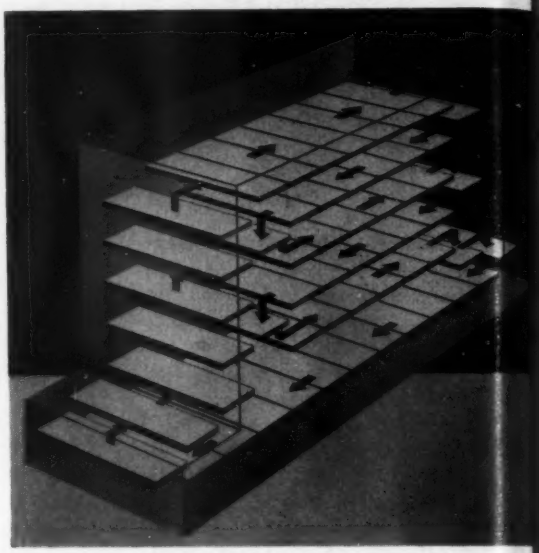

Fig. 1: Schematic view to illustrate the material flow in t Transvertical Lehr. This perspective view is used rat than a standard sectional drawing because it provides m graphic representation of the actual material flow.

Materials Handling Mechanism

The materials handling mechanism of this lehr is p ticularly interesting. The trays loaded at the left-hand end of lehr, as shown in Figures 1 and Each tray then moves forward into the lehr proper, rising upw in a series of increments, as succ sive loaded trays are pushed i the lehr. After reaching the top the elevator chamber, the loa tray moves horizontally across top pass of the lehr to the extre right-hand end. At this point, lowerator mechanism drops the t to the next horizontal pass. On t second level, the tray is pus across the lehr to the left-hand of the lehr. Since one tray pu against another, there is a conti ous procession of loaded trays m ing across each level of the lehr

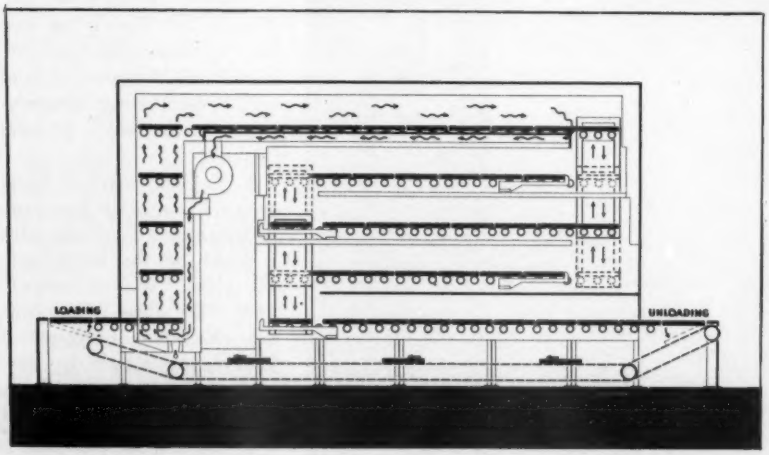

Fig. 2: Simplified longitudinal sectional drawing of the Transvertical Lehr showing heat flow and tray movements.

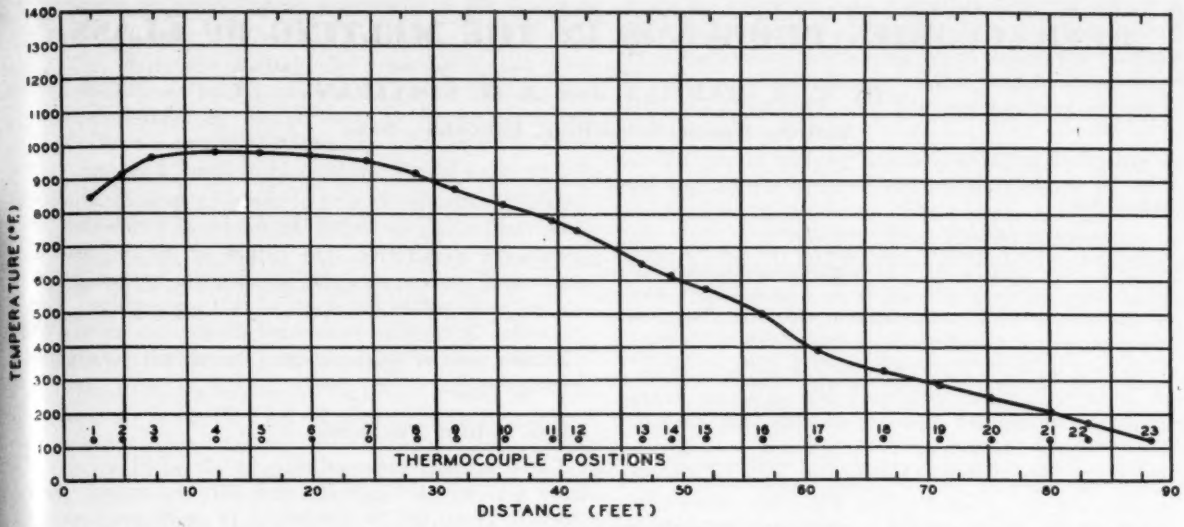

Fig. 3: Typical temperature curve for glassware annealed at The Jeannette Glass Company in the Transvertical Lehr.

any given time, the movements being in steps of one tray length.

The incremental movements of the trays are harmonic in nature, proving extreme smoothness of operation and safety in handling the hot glass. A total of five horizontal passes completes the annealing cycle and the tray is pushed out onto the discharge platform shown at the right. The ware is then unloaded and the tray drops down to the tray return conveyor below. The tray is then returned to the charge end of the lehr for reloading and a repetition of the cycle.

Heat Application System

Heating is accomplished by means of a series of atmospherical burners located in the bottom of the elevator chamber. In this manner, the heat is applied to the ware before it has an opportunity to cool down to such temperatures as would develop substantial stresses. This also eliminates part of the reheating to the required annealing temperature.

By using atmospheric burners as the source of the heat, the need for compressed air is eliminated. Natural gas at low pressures is used as the fuel at Jeannette. Heating is controlled by means of a thermocouple located at the top of the elevator chamber. Control from this point seems to be optimum in providing the desired annealing curve. Additional heat is supplied by means of pipe burners located at the charge end of the lehr. These pipe burners preheat the trays to eliminate any thermal shock which might result from loading the hot ware on cold trays. This preheating also helps to maintain the ware at temperature, prior to entering the elevator chamber of the lehr. The lehr has a maximum temperature of 1050°F. which is ample to anneal the ware produced at The Jeannette Glass Company.

The heat is applied to the ware during its passage upward through the elevator and across the first horizontal pass as shown in Figure 2. At the end of the first horizontal pass, the heated air enters a horizontal duct and is returned by means of a recirculating fan and a vertical duct to the combustion zone at the base of the elevator chamber. This procedure provides continuous circulation of heated air at the temperatures required to produce the annealing curve. Variations in the heat flow and thus the annealing curve can be attained through the control thermocouple at the top of the elevator chamber, as well as the vents located in the horizontal duct work. Typical curves for various types of ware are shown in

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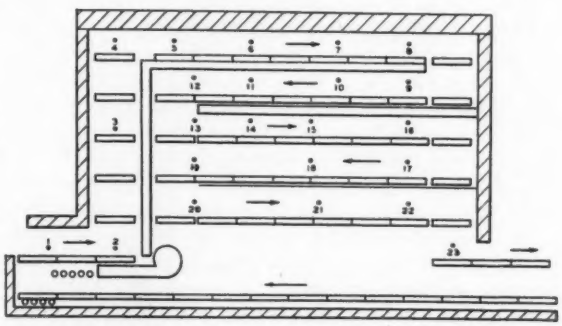

Fig. 4: Locations at which thermocouple measurements of temperatures plotted in Figure 3 were taken.

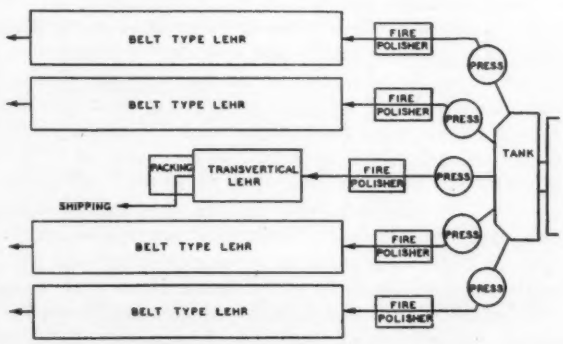

Fig. 5: Schematic plan layout of production lines at The Jeannette Glass Company, showing location of Transvertical Lehr.

REFRACTORIES PROBLEMS IN THE MELTING OF GLASS

By C. G. HARMAN and J. D. SULLIVAN

Battelle Memorial Institute, Columbus, Ohio

Abstract

An important problem in glass manufacture is the procurement of suitable refractory materials for the construction of glass melting equipment. The requirements of these materials vary widely, depending on the location and function of the material in the glass melting structure. The service life of glasshouse refractories also is dependent on numerous related and complicated variables. Good progress has been made in the development of refractories. Future progress is contingent to a large extent on cooperation between glass production personnel, glass technologists, and refractory manufacturers.

Refractories employed in glassmaking equipment are subject to both chemical and mechanical attack in service. The fundamentals of refractory corrosion are imperfectly understood. Molten glasses, however, are extremely corrosive, and the corrosive tendency increases with temperature. Each type of glass, such as soda-lime-silica, lead borosilicate, sodium borosilicate, fluoride opal glasses, and the like, produces characteristic corrosion patterns, which result from direct chemical reaction between the components of the glasses and refractories. Erosive influences in the glass melting equipment are equally damaging to refractories. Solution of the refractory components in the glass, coupled with the abrasive action of the raw batch and the molten batch, mechanical and thermal shock, and other similar physical factors, are examples of conditions which contribute to failure of the refractories in service.

Introduction

One of the primary problems of manufacturers of glass is that of obtaining suitable materials for the construction of glass melting apparatus. Glass, as well as the materials from which it is made, is a solvent for everything with which it may come in contact at high temperatures. There is no possibility of an equilibrium between the glass and the refractories forming the basin which contains the melt. Superstructure refractories are also subjected to continuous attack by gases, vapors, and dusts.

The problem, therefore, is to reduce the rate of attack on the refractories to a minimum and, at the same time, maintain a maximum output of glassware. The glass manufacturer seeks to do this by control of the many variables and intangibles in connection with glass furnaces and glass melting to give the best over-all dollar balance. The current trend in glass melting is toward greater production per units of furnace area and toward higher operating temperatures in order to obtain an improvement in both quality and quantity of production.

A limiting factor in furnace design and glass melting practice has always been the refractories available for furnace construction. The modern trend of higher production rates and higher operating temperatures is in the direction to accentuate the already critical refractory problem. The industry, however, has more than held its own under the pressure of intensified competitive conditions and increased costs, as average melting costs currently compare favorably with those of fifteen years ago.

Progress being realized marks the entrance of the industry into an era of improved glassmaking efficiency based on better refractories. This paper is confined to a general discussion of some of the more important problems confronting the technologist engaged in research on glasshouse refractories. The nature of the subjects of stones and cords is such that an adequate treatment cannot be given within the scope of this presentation. The discussion is confined to selected illustrations chosen to illustrate some of the basic requirements of refractories during use.

A paper presented before the Forty-Third Annual Meeting of the American Institute of Chemical Engineers.

Glass Melting Furnaces

Glass melting furnaces may be classified into two main groups: (1) periodic and (2) continuous. The periodic group can be considered to cover pot melting and day-tank melting. These and continuous tanks are further classified with respect to the method of heating: regenerative, recuperative, and direct fired. The refractory problems of electric melting furnaces, which are still in the development period, are not discussed in this paper. Each furnace has some problems directly dependent on the design and mode of operation, but there are quite a number of specific variables commonly applicable to the general process of melting. The problem of refractories for the pot melting of glass is considered to differ somewhat from the problem of tank refractories because of the large range of glass compositions melted in them and the conditions and manner of use. The larger portion of the country's glass is melted in continuous regenerative tanks. Sketches of a typical furnace of this type are shown in Figures 1 and 2. The

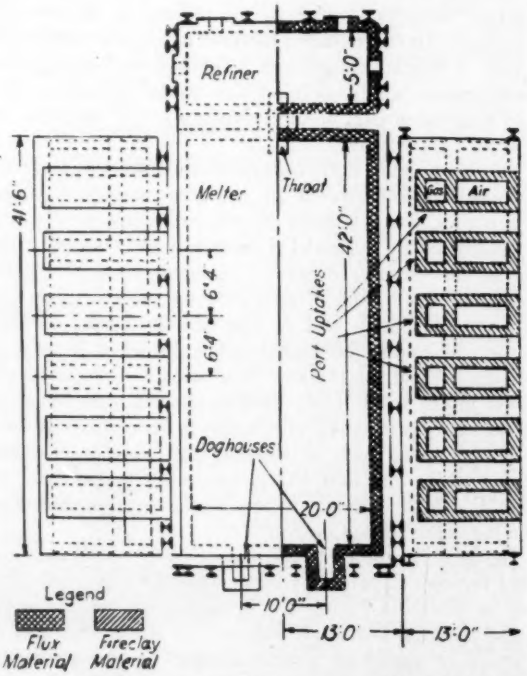

Fig. 1. Plan view of regenerative-type glass furnace[1].

furnaces generally consist essentially of the following parts:

(A) *Basin for melting and retaining molten glass.* 1) Doghouse (batch-feeding area), 2) Melting zone, 3) Refining zone, 4) Bridge wall, 5) Feeder forehearth. (B) *Superstructure.* 1) Main furnace crowns, 2) Ports: a) crowns, b) arches, c) bottoms, d) end walls, e) sidewalls, f) jambs, g) sills. 3) Tuckstones, 4) Breastwalls, 5) Bridgewalls. (C) *Regenerators.*

This outline is by no means complete and includes only those furnace parts considered essential to the present discussion.

Factors Influencing Refractory Deterioration

The variables influencing the life of glasshouse refractories are a complex interdependent group generally regarded as glass melting, refractory, and furnace-operation problems. Some of the factors may be segregated to permit consideration of their contribution to the over-all service.

(1) Glass Melting Process. The glass melting operation, as it affects refractory wear, may be considered as consisting of four variables: (1) glass composition, (2) batch composition, (3) melting temperature, and (4) rate of melting. Each of these can be broken down further to smaller subheadings which are, in turn, related in such a manner that the effect of each must be considered in its relationship to the others, as well as its own particular effect.

(a) *Glass Melting Reactions.* Glass melting reactions may be considered by discussing the melting of a simple soda-lime-silica batch calculated to give the following glass:

Constituent	Amount Per Cent by Weight
SiO_2	72
CaO	12
Na_2O	16

As the raw materials (soda ash, limestone, and sand) are heated, the following reactions take place:

$$Na_2CO_3 + CaCO_3 \rightarrow Na_2Ca(CO_3)_2$$
$$Na_2Ca(CO_3)_2 + SiO_2 \rightarrow Na_2O{\cdot}CaO{\cdot}SiO_2 + CO_2$$

The reactions start as low as 1115° F., but the speed is slow below 1580°F. A liquid composed of 73.5 per cent of SiO_2, 5.2 per cent of CaO, and 21.3 per cent of Na_2O is a stable phase at 1340°F.[2] This liquid constitutes about 66.5 per cent of the total mass, leaving 22.7 per cent of SiO_2 and 10.8 per cent of CaO as the balance.

As the temperature rises, and as more lime and silica are taken into solution, the liquid approaches $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ in composition. During the solution of the quartz grains, which are last to dissolve, localized areas of high viscosity glasses about the sand grains tend to retard the rate of solution. Because the silica has only a small tendency to diffuse in the glass, this highly viscous liquid must be removed from the vicinity of the sand grains in order to facilitate its solution. The siliceous residue, which is less dense than the main glass, also has some tendency to float to the surface.

The rate of melting can be speeded up by increasing the melting temperature and by the addition of minor constituents to the batch. These minor batch materials are intended to improve the melting by slightly improving the high-temperature physical properties of the liquid and by inducing a "boiling" action during the melting process. This latter phenomenon improves the melting operation by its stirring action, and improves the quality of the melt by sweeping out small occluded gas pockets. Small additions also are made for the purpose of controlling the color of glasses. Because such additions change the absorption characteristics of the molten glasses for heat radiations, rates of heating, temperature gradients, convection currents, etc., also are affected. The chemical activity of glasses toward the refractories also is changed by such additives.

These two methods of improving the melting add to the existing items responsible for refractory wear. Increasing the temperature causes an increase in the rate of reaction of dusts, liquids, and vapors on the refractories. The minor batch constituents increase the vapors and dusts both by increased "boiling" action in the melting batch, and by adding to the quantity of those which normally are present.

(b) *Minor Batch Constituents.* Minor constituents, such as CaF_2, Na_2SO_4, and $BaSO_4$, improve the glass melting process by producing a more nearly homogeneous ("plain") glass more rapidly. These allow the furnace load to be increased, keeping a good glass as the end product. Minor amounts of sulfates, however, cause side reactions to occur which are, as far as the refractories are concerned, a complication that may become serious.

Na_2SO_4 and $BaSO_4$ will react with batch constituents to give the oxides, with SO_2 as the evolved gas. The SO_2, however, will react almost instantaneously with Na_2O vapors present above the melt. Na_2SO_4 will attack SiO_2, Al_2O_3, and other constituents present in the glass furnace, forming corrosive liquids. The formation of

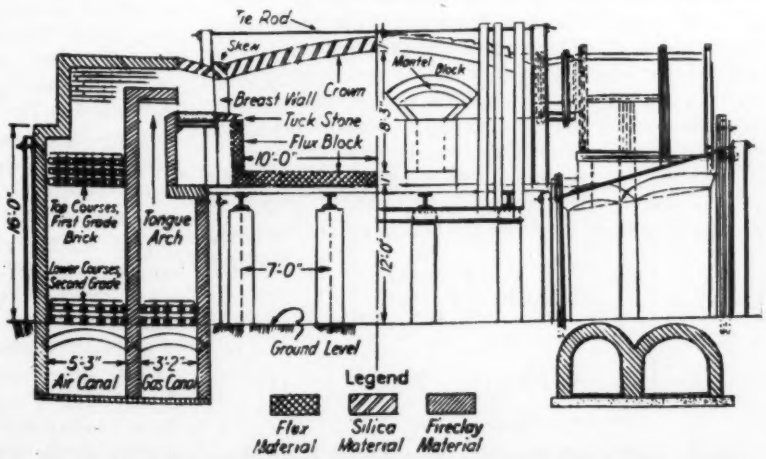

Fig. 2. Section through the first port of a regenerative-type glass furnace[1].

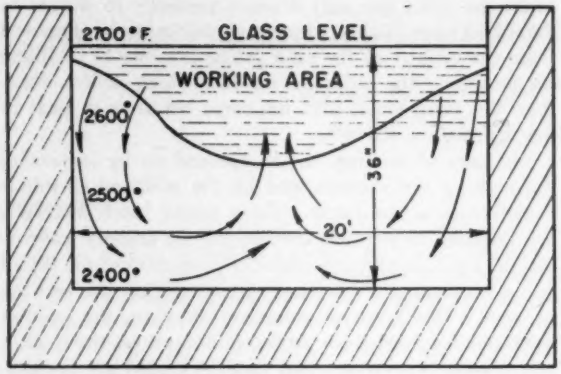

Fig. 3. Illustration of possible currents in a transverse section of a glass tank[6].

Na_2SO_4 is enhanced further by the presence of SO_2 from the burning fuel. Since decomposition of Na_2SO_4 is only 13.1 per cent per hour at 2715°C.[3], the presence of this salt is considered with concern. The corrosive nature of molten sodium sulfate is well known, and is widely used as the primary solvent for silica-alumina refractories in analytical chemical procedures. Sodium sulfate tends to be immiscible in glasses and to float on the molten glass.

(2) Refractory Use. Each part of the furnace must be constructed of materials best suited to withstand the corrosive action of the liquid, vapor, and dusts to which it will be exposed. At the same time, certain other qualifications must be met which will govern the usage. Some of the more important points of use are described in the following paragraphs.

(a) *Melter Sides Below Glass Level.* The melter sides form part of the container for the liquid. The desirable properties include low porosity, uniform tight structure, and a composition designed to provide a uniform and minimum amount of wear, depending on the glass melted. This latter part includes glass composition, batch constituents, rate of melting, and temperature of melting. The most typical failure of this refractory is the so-called metal-line cut where, owing to the action of the corrosive liquids and vapors, the refractory often is eroded through to the outside. The metal-line cut has been the subject of much speculation and discussion. The tendency to attribute the cause to temperature gradient alone, however, is in error[4]. A simple laboratory experiment in which a small specimen is rotated in a crucible containing glass, which has no appreciable temperature gradient, will show the same type of severe metal-line cut.

The rate of corrosion of tank blocks increases rapidly with increasing temperature. A study of this important problem led Blau[5] to derive the following relationships:

$$\log \frac{S_1}{S_2} = 22{,}800 \frac{(T_1 - T_2)}{T_1 - T_2} \qquad (1)$$

$$\log \frac{S_1}{S_2} = 0.0024\,(T_1 - T_2) \qquad (2)$$

where S_1 and S_2 are the rates of corrosion at temperatures T_1 and T_2, respectively. In equation (1), the temperatures are in degrees Rankin, but in equation (2) they are in degrees Fahrenheit. The constants were derived from data on the corrosion rates of bonded clay refractories in contact with soda-lime glass. According to Blau, the equation holds for quite a range of refractories, but the relations may be altered by even minor variations in glass compositions.

If all other things are constant, including the ultimate composition of the glasses, the batch composition may be altered to reduce the corrosive effect of the batch. The raw batch is more chemically reactive on refractories than the molten glass, which is one of the reasons so much thought and effort has been given to batch feeding methods. In general, however, the ultimate composition of the glass, as well as the batch compositions, usually is fixed, and is not altered merely for the purpose of changing the rate of attack of the refractories by the metal.

Glasses of different compositions each appear to have their own characteristics in regard to their attack on flux blocks. Soda-lime-silica, borosilicate, and fluoride opal glasses each tend to produce more or less characteristic erosion and corrosion patterns. Fluoride glasses are particularly corrosive and cause corrosion of the tank block, even at considerable depths below the metal line. Also, when fluorspar or cryolite is used as a batch ingredient, it tends to settle and spread on the floor of the tank. The resulting low-viscosity corrosive fluid attacks the floor blocks and sooner or later loosens bits of refractories, which become a source of objectionable "stones" as they flow into the melt. This type of corrosion and its associated stone difficulties has been minimized either by cooling the bottom or by substituting refractories more resistant to attack by fluorides, such as fusion-cast high-alumina refractories.

In general, the fundamentals of refractory corrosion by glass are, at best, imperfectly understood. Up to the present time, a lack of agreement exists even as to whether the predominant factor is chemical or physical in nature. It seems entirely logical to believe that, since comparatively small changes in glass compositions often alter the corrosion characteristics radically, the physical changes induced into the glass by small chemical changes could be the predominant factor.

The melt in the tank is by no means static. The glass is subject to considerable movement, owing to convection, batch charging, gas evolution, drawing of glass from the work, and drainage of slag from refractories above the metal. Several other factors contribute to variations in the liquid-glass movements, such as temperatures and temperature fluctuations, furnace insulation, furnace design, and changing thickness of refractories. A schematic illustration of currents in a section of a tank is shown in Figure 3.

Tank blocks below the metal line corrode in a characteristic manner, an example of which is shown in Figure 4. Several theories have been advanced in explanation of the shapes of the eroded surfaces of flux blocks. A plausible explanation is that the interfacial reaction product of refractory and glass is a liquid of such density that it drains downward on the surface of the block causing the characteristic contour. The reaction product on the refractory at the metal line would have dissolved, as yet, little refractory, and consequently

would be most corrosive in a zone near or just below the surface of the glass. As the interfacial reaction liquid drains farther downward on the surface of the refractory, it tends to become richer in the refractory constituents, more viscous, and less corrosive. As the contact glass moves downward, its viscosity also increases at the lower temperatures and its rate of drainage is retarded. Obviously, such downward drainage tends to remove refractories both by chemical action and by erosion.

It is not surprising, therefore, that different types of refractories behave differently in their corrosion characteristics, or that the corrosion characteristics of different glasses on refractories also vary widely. Quite different profiles would be expected on a refractory having an interfacial layer less dense than the tank glass.

Other and larger currents take place in the tank as a whole which contribute characteristic wear in certain locations, depending on tank design and tank operation. A pronounced illustration of such wear is observed in the throat where the velocity of moving glass is relatively high.

The viscosity of the glass in the tanks has a direct bearing on tank-block erosion inasmuch as it is a predominating factor in liquid movement and chemical diffusion within the glass.

Lower temperatures and high viscosities of glass in contact with the refractories tend to promote longer refractory life. This sometimes is accomplished by artificial cooling. The matter of cooling and insulation of tanks is a complex problem and no generalizations should be made. These choices are made on the basis of fuel economy, operating efficiency, and other factors.

Choice of Refractories

The ideal refractories for tank linings would have the following characteristics: (1) ability to resist the action of heat to the extent of showing no change from the solid state; (2) sufficient homogeneity to dissolve evenly and uniformly and produce no seeds, stones, or cords; (3) minimum solubility in the particular glass, for the refractory should not be a source of chemical discoloration, owing to the solubility of colored ions from the refractories; (5) low thermal conductivity; and (6) high resistance to thermal stresses and to spalling.

(1) Refractories Below Glass Level. (a) *Melting-End Refractories.* Formerly, conventional flux blocks were made of fire clay and, to a lesser extent, of the bonded alumina-silicate materials, but fusion-cast materials currently have been adopted by many plants because of their higher inherent refractoriness and lower rate of solubility in molten glass. Some plants use a construction of fusion-cast sidewalls and clay bottoms. The use of clay flux blocks is said to result in better heat economy, but shorter life and more glass contamination than from the use of fusion-cast materials. A balanced construction is preferred by some flint glass manufacturers of fusion-cast and clay flux block, designed to give the best combination from the standpoint of fuel economy and life. Where longest run life and minimum color pickup from refractories are required, all fusion-cast blocks may be used, but at an increased expenditure of fuel per ton of glass.

(b) *Throat.* In the throat, where the corrosion is at a maximum and where it is desired to maintain the original throat area as long as possible, fusion-cast refractories are almost always used.

Extensive work is being directed toward the improvement of the refractories used as the throat cover. The strong corrosive action of the hot melt is most pronounced on the upper surface. The condition of used refractories taken from this area is probably indicative of the cause of unusually severe corrosion. Examination of a worn refractory usually reveals a severely pitted surface, commonly referred to as "upward-drilling". This might result from surface tension effects in which dissolved gases play no small part.

(c) *Refining End.* Generally speaking, the same materials are used in the refining end as in the melting end, although service requirements are somewhat less severe.

(2) Refractories in the Superstructure. (a) *Tank Crown.* The melter crown, because of its high hot-load-bearing requirement, is commonly constructed of silica of either standard or premium grade. In smaller furnaces, the crown sometimes is constructed of bonded mullite, sillimanite, or kyanite-type refractories. The use of higher temperatures in the melter has required the application of higher purity, premium-grade, silica crown brick, especially where crown drip has been excessive with standard silica crowns.

Gases and vapors will cause some wear but, if the flame is not impinging on this part, the gas movement is relatively low. The precautions observed should include careful control of the melt vapors. An example of the latter problem is the production of high-FeO glass, where the FeO vapors can develop a very fluid glass with silica.[7]

(b) *Breastwalls and Endwalls.* Owing to increased temperatures and loads, breastwalls, which a few years ago were nearly always built of silica refractories, in many cases have been replaced by fusion-cast refractories or by bonded kyanite. A fairly common custom is to use a balanced construction, using a combination of fusion-cast materials and bonded kyanite, at least for those por-

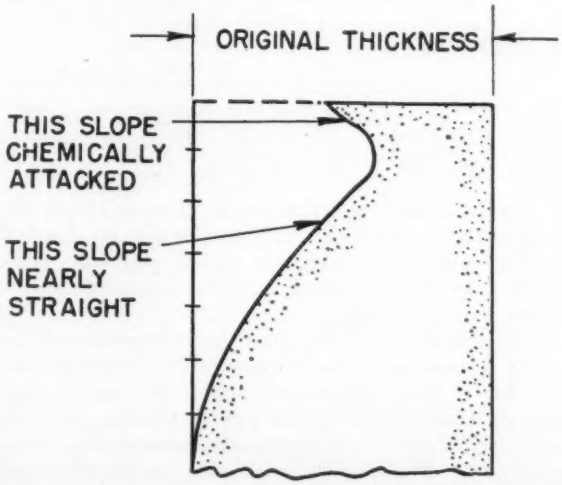

Fig. 4. Characteristic profile of an eroded tank block made of bonded fire clay[6].

tions where conditions are most severe. Several types of refractories have been tried to a limited extent.

Endwalls (back end or feeder end) require a highly refractory brick of good strength. Silica brick and high-alumina refractories have been used. In general, the requirements of wall refractories are about the same as those for ports.

(c) *Glass Furnace Ports.* The high concentration of vapors and dusts at the maximum furnace temperatures causes severe wear on the port sills, jambs, arches, and paving, especially at the ports nearest the charging end. This has led to the use of special refractories, usually of a highly refractory nature, with a composition and structure intended to give maximum corrosion resistance.

The ports nearest the feeding end of continuous side-port regenerative glass tanks receive the severest wear owing to the high dust content of the exhaust gases and to the higher temperatures. These port sills, jambs, and arches that are invert use a refractory of the same type and composition as that used in contact with glass. Sidewalls between these ports frequently incorporate a high-alumina super-refractory of the fired type.

(d) *Regenerator Checkers.* The regenerator refractories must resist both the corrosive action of dusts and vapors and the thermal shock imposed by the regenerative system. As the corrosive action depends on surface exposed, and erosion depends on bonds between grains, a tightly bonded dense material would be best. These properties, however, are deleterious to thermal-shock resistance. Because thermal shock is probably the most important of the two separate actions, checker bricks are designed to withstand thermal shock. There are, however, certain precautions which can be exercised to give increased life in these refractories. These precautions depend, in general, on the kind of glass melted. Examples are the practices exercised in melting soda-lime-silica and borosilicate glasses. The details are described briefly as follows:

1) *Soda-lime-silica glass.* If the sand used in the batch is selected with the particle sizes coarser than 200 mesh at a minimum, the dusting from this material is greatly reduced. This, then, leaves the composition of the dust and vapors carried over into the checkers on the basic side. By using a basic refractory, the corrosion is materially reduced.

2) *Borosilicate glass.* The strong vapor of B_2O_3 coming from a melt of this type precludes the use of basic brick in the checkers. Refractories for these applications can best be of the Al_2O_3 — SiO_2 type.

A wide variation exists in the use of materials for the construction of checkers. All grades of fire clay, bonded high alumina, silica, magnesite, chrome magnesite, periclase, and forsterite, and all grades of fusion-cast refractories, have been used.

The service to be expected from regenerator refractories depends on so many factors that it is virtually impossible to cover the subject within the scope of this paper. Alumina-silica checkers of the fire-clay type give good service, but are subject to slag erosion under severe conditions. High-alumina brick offer less trouble from slag formation and erosion, but tend to react with alkaline dusts and fail by a "shelling off". Basic brick are not subject to these failures, but are subject to a loss of bond when exposed to reducing conditions.

The factors which have raised the requirements of refractories in contact with the glass are having a similar effect on regenerator refractories.

Conclusion

In summation, more detailed work must be done on the corrosion resistance of refractories. A better understanding of the melting phenomena will assist in this direction. Some progress has been made on melting the batch where temperature and grain-size studies have shown optimum conditions for a given glass composition, but more studies are needed on the effect of minor impurities on the rates of corrosion.

The problems of glasshouse refractories still remain, even though great advancements in flux blocks have been made. Even if the industry were content with the best in flux blocks now available, a considerable number of glasshouse refractory problems yet await future improvement.

Many of the applications for refractories in the glass industry might be considered as special and, because of the apparent lack of tonnage, only limited effort is spent on the development of improvements. A further obstacle to the development of glasshouse refractories is the requirement of a combined knowledge of glass technology, glass tank operation, and refractory manufacturing. Technologists and engineers with a good grasp of these fields should be in a good position to contribute substantially to progress in the development of improved refractories for glass manufacturing. Still needed is an understanding of the fundamentals of glasshouse refractory corrosion and deterioration, and more accurate and rapid methods of evaluating them.

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G.C.M.I. SPRING MEETING

The Board of Trustees of the Glass Container Manufacturers Institute has announced that the 1951 Spring Meeting will be held at The Greenbrier, White Sulphur Springs, West Virginia, on Monday, Tuesday, and Wednesday, May 21, 22, and 23.

The meeting will provide an opportunity for the Board of Trustees to receive semi-annual reports from the nine standing committees and to make these reports available to the membership, and to hold the Annual Membership Meeting for, among other things, the election of one Trustee to serve a two-year term and four Trustees to serve a three-year term.

The Board has appointed the following Program Committee to work with the business management: P. I. Heuisler, Jr., F. B. Pollock, H. C. Herger, S. L. Rairdon, and B. W. Cremers. A complete program of the several meetings will be announced at a later date.

Inventions and Inventors

Annealing

Lehr Temperature Control. Fig. 1. Patent No. 2,544,947. Filed Jan. 19, 1946. Issued Mar. 13, 1951. Three sheets of drawings. Assigned to Pittsburgh Corning Corp. by Arvid H. Baker.

This lehr is particularly adapted for annealing cellulated glass blocks and because of the size and structure of these blocks, a large and long tunnel is necessary. The lehr is divided into some 20 or 30 sections of temperature zones about 5 feet long. The temperature in each zone is controlled by the arrangement shown in the figure which is duplicated on the other side of the tunnel.

The usual lehr belt 21 carries the blocks 17 through the tunnel which has partitions 29 on both sides forming ducts 28. The air is circulated by a fan 34 and heated by a burner 44 so as to send the hot air as indicated by the arrows. Baffles 51 and 56 are placed on the bottom of the tunnel. A thermostat 57 actuates a damper 48 through an automatic mechanism such as shown. Automatic means is also provided to regulate the temperature of the room containing the lehr.

The patent contains 13 claims and 11 references were cited.

Feeding and Forming

Drive for Forming Machines. Fig. 2. Patent No. 2,540,154. Filed Mar. 12, 1947. Issued Feb. 6, 1951. Five sheets of drawings. Samuel E. Winder, the inventor, assigned one-half interest to Henry C. Daubenspeck.

This device is a drive connecting a feeder and a forming machine by which the forming machine may be shut down while the feeder continues to operate and which will establish the proper timed relation between the two when the forming machine is started again.

The diagram shown in the figure discloses a bottle forming machine 30 having a table 31 driven by a shaft 35. The feeder is driven through a timer 38 operated by a shaft 40. The feeder and the former are both driven by a large motor 42, the connection being through a synchronizer 50. There is another small motor, not shown in the figure, which can drive the feeder timer 38 and the synchronizer 50.

The motor 42 drives the shaft 48 faster than it is driven by the small motor. Speed changing devices are provided to regulate the speed of the driven parts in both cases. When the large motor 42 operates, it drives the forming machine and the feeder timer. If the motor 42 is stopped the small motor will continue to run the feeder timer so that the feeder continues to operate. Mechanism is provided to insure the proper timed relation between the forming machine and feeder when the forming machine is again thrown into operation.

The patent contains 17 claims and the references cited were 1,692,589, Soubier, Nov. 20, 1928; 1,951,875, Laabs, Mar. 20, 1934; 1,996,579, Johnstone et al., Apr. 2, 1935; 2,026,023, Du Bois, Dec. 31, 1935; 2,105,914, Fritzsch, Jan. 18, 1938; 2,167,676, Pechy, Aug. 1, 1939; 2,308,926, Kreis, Jan. 19, 1943; and 2,330,985, Meyer, Oct. 5, 1943.

Furnaces

Electric Furnace. Fig. 3. Patent No. 2,538,956. Filed Aug. 18, 1945. Issued Jan. 23, 1951. One sheet of drawings. Inventor Pierre Arbeit, Paris, France, assignor to Societe Anonyme des Manufactures des Glaces et Produits Chimiques de Saint-Gobain, Chauny & Cirey, Paris, France.

The figure shows a tank 1, two refining "cells" 2 and 3, and feeders indicated at 4 and 5. The "cells" seem to be what we call a forehearth and these are heated by electrodes 6 and 7. The tank proper is heated by burners 8 and 9. The tank is divided into two compartments 11 and 12 of a size corresponding to the amount of glass supposed to be drawn by the feeder attached to the compartment. Doghouses (as known in this country) 13 and 14 deliver batch to the two compartments which may be of different composition.

The patent contains two claims and 15 references were cited by the Patent Office.

Glass Compositions

Tarnish Resistant Glass. Patent No. 2,542,489. Filed Mar. 26, 1947. Issued Feb. 20, 1951. No drawings.

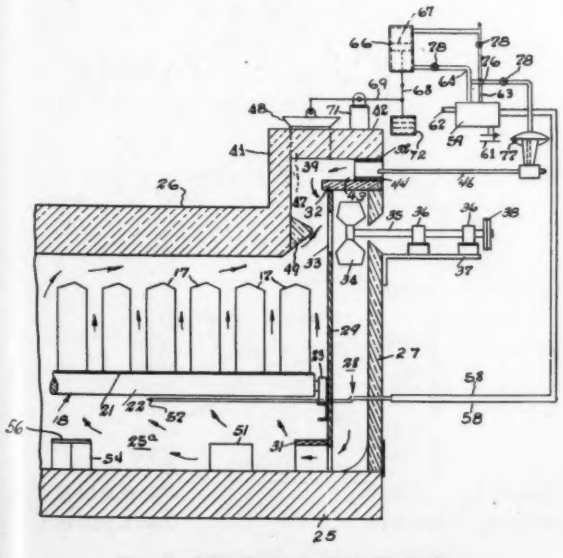


Fig. 1. Lehr Temperature Control.

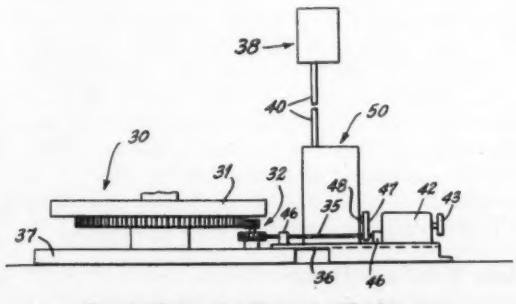


Fig. 2. Drive for Forming Machines.

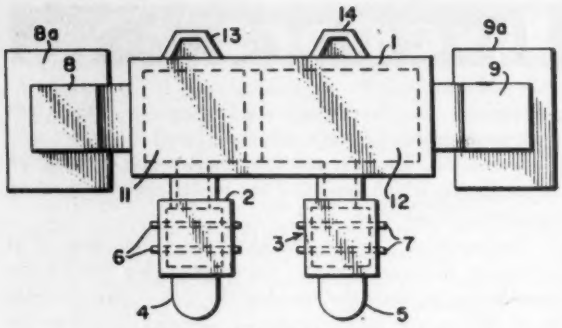


Fig. 3. Electric Furnace.

Assigned to Pittsburgh Plate Glass Co. by James E. Duncan.

This glass is intended particularly for optical use, such as in bifocal lenses. The following table gives five examples of glasses coming under this patent, the ingredients being given as percentage by weight:

	1	2	3	4	5
SiO_2	42.00	43.09	43.09	43.04	43.42
BaO	36.07	35.35	31.43	36.52	36.82
K_2O	4.09	2.22	2.22	2.25	....
Li_2O	1.95	3.76	3.76	3.76	5.68
B_2O_3	6.94	6.50	6.50	6.52	10.52
ZnO	....	4.39	4.39	4.38	....
PbO	5.92	....	6.07	....	....
TiO_2	2.48	2.54	1.98	2.98	3.00
Sb_2O_5	.42	2.02	.43	....	.43
As_2O_5	.13	.13	.13	.55	.13

Each of the glasses has an index of refraction greater than 1.60 and a reciprocal of dispersion (nu value) higher than 50. The other characteristics of the glasses are such as to adapt them to use in the manufacture of ophthalmic devices.

The patent contains four claims and the references cited were 1,765,287, Scott, June 17, 1930; 2,018,817, Taylor, Oct. 29, 1935; 2,413,549, Deyrup, Dec. 31, 1946; 2,414,504, Armistead, Jan. 21, 1947; 2,433,883, Armistead, Jan. 6, 1948; and Morey: Properties of Glass (1938), pages 85, 101, 406, 408, 409, 410, 411.

Optical Glass. Fig. 4. Patent No. 2,544,460. Filed June 23, 1947. Issued Mar. 6, 1951. One sheet of drawings. Assigned to Bausch & Lomb Optical Company by Norbert J. Kreidl.

This patent relates to a high index phosphate glass. In the figure, the upper part is a graph which represents glass compositions of the ternary system BaO — La_2O_3 — P_2O_5. The lower part shows the relative indices of refraction between the lanthanum and barium present.

The patent contains three claims and the most specific one reads: An optical glass composition consisting of approximately from 42% of barium metaphosphate and 58% of lanthanum metaphosphate to 75% of barium metaphosphate and 25% of lanthanum metaphosphate.

No references were cited by the Patent Office.

Glass Wool and Fiber

Electric Furnace for Making Fibers. Fig. 5. Patent No. 2,540,415. Filed May 9, 1949. Issued Feb. 6, 1951. One sheet of drawings. Emanuel Altman, Prague, Czechoslovakia, inventor.

The circular tank 1 has a series of spinning nozzles 2 and is enclosed by the usual refractory casing. The central part 6 is tubular and has a series of holes 17 above the glass level through which a neutral gas, such as N_2, passes coming from a supply pipe 16. The glass is heated by current from terminals 8 and 9. The fibers are enclosed below the furnace by a cylindrical casing 13 made of heat-resisting glass. The fibers pass out through an opening in the bottom of the casing 13 and go to a winding drum.

The patent contains two claims and the references cited were 614,927, Burton, Nov. 29, 1898; 1,427,014, Von Pazsiczky, Aug. 22, 1922; 2,159,361, Atkinson et al., May 23, 1939; 2,212,528, Slayter, Aug. 27, 1940; 2,225,667, Staelin, Dec. 24, 1940; 2,229,489, Barnard, Jan. 21, 1941; 2,244,267, Slayter et al., June 3, 1941; and 512,700, Great Britain, Sept. 22, 1939.

Sheet and Plate Glass

Sheet Drawing Machine. Fig. 6. Patent No. 2,543,225. Filed Sept. 22, 1945. Issued Feb. 27, 1951. Two sheets of drawings. Assigned to Pittsburgh Plate Glass Company by Louis J. M. Bonjour, St. Jean des Vignes, France.

This invention improves the quality of glass made by the Pittsburgh and Fourcault processes by controlling the air currents near the sheet as it leaves the pool of molten glass. On each side of the sheet 2 there is a cylindrical "paddle" or fan 1 and 1a which extends the full width of the sheet. These are driven in the direction of the arrows and so set up a positive current of air. In one embodiment, the blades are in the form of helices and

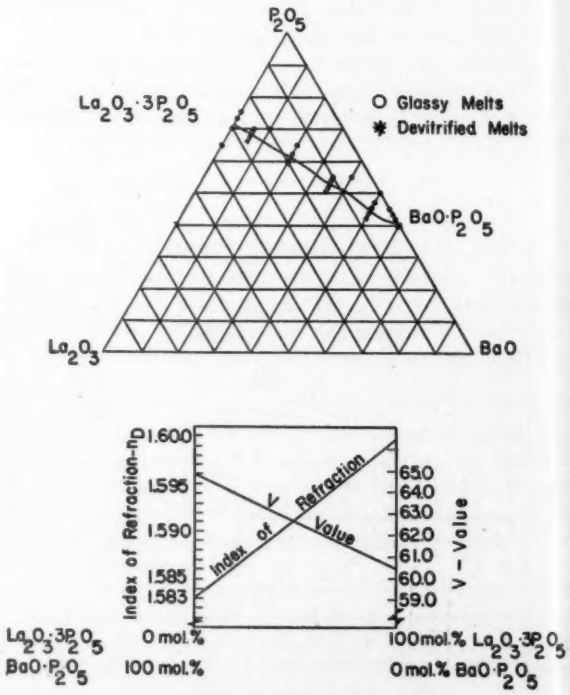


Fig. 4. Optical Glass.

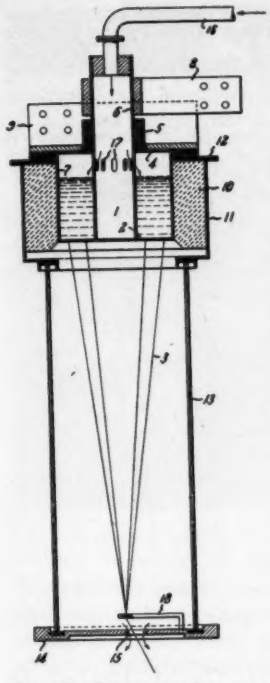


Fig. 5. Electric Furnace for Making Fibers.

there may be more than one fan on each side. The blades come close to the sheet being drawn.

The patent contains three claims and the references cited were 2,002,544, Monro, May 28, 1935; 2,116,693, Bishop, May 10, 1938; 2,158,669, Amsler, May 16, 1939; 2,201,286, Bundy, May 21, 1940; 2,278,328, Magrini, Mar. 31, 1942; 2,287,136, Rolland et al., June 23, 1942; and 17,958, France, Jan. 16, 1857.

Tube and Cane Machines

Tube Bending Machine. Fig. 7. Patent No. 2,542,325. Filed Feb. 24, 1947. Issued Feb. 20, 1951. Two sheets of drawings. Assigned to General Electric Company by Alfred Greiner and August W. Seitz.

The patent relates particularly to the bending of tubes for use in lamps and for positioning the exhaust tube. In the figure the tubular lamp 1 and metal cap 2 are set into a holder so that the exhaust tube 4 is in a movable holder 5. The exhaust tube is heated by burners 43 and 44 which are removed after the heating operation by the crank 45. The exhaust tube is bent to proper position by means of the knob 53. The apparatus is designed for use in connection with the mechanism shown in Patent No. 2,494,872.

Complete operating mechanism is shown in the patent which contains seven claims and the references cited were 2,265,070, Goode, Dec. 2, 1941 and 2,439,902, Noel, Apr. 20, 1948.

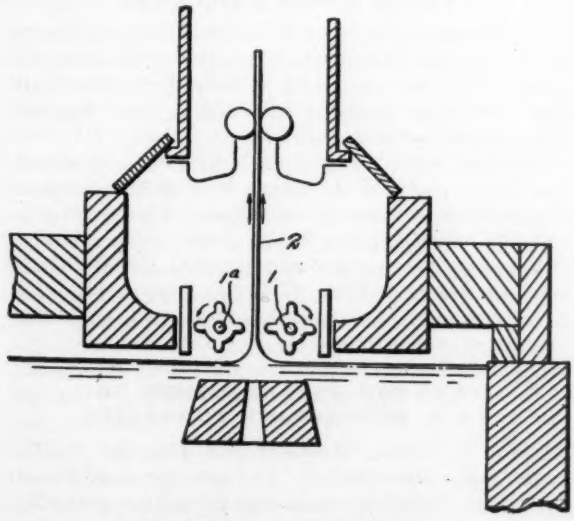


Fig. 6. Sheet Drawing Machine.

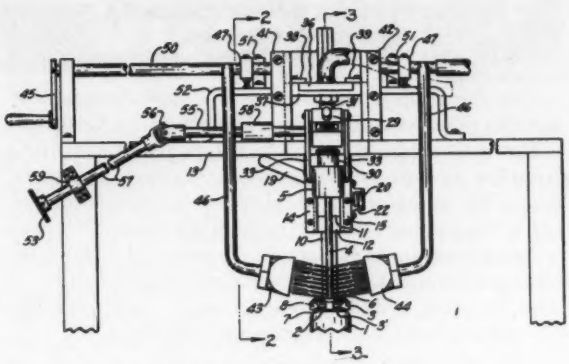


Fig. 7. Tube Bending Machine.

Miscellaneous Processes

Glass-Sand Treatment. Patent No. 2,523,996. No drawings. Assigned to Brockway Glass Co., Inc. by James P. Poole, State College, Pa.

The single claim of the patent reads as follows: The method of treating glass-making sand of approximately 50 mesh and having tenacious surface impurities which comprises wet grinding in a pebble mill wherein the pebbles are of the order of three-fourths of an inch in diameter, the water approximately reaches the upper level of the charge, the charge is approximately half the capacity of the mill, and the ratio of sand charge to pebble charge is of the general order of 1 to 8, for a period of time sufficient to separate the surface impurities from the particles as slime by attrition of the particles and the particle size is reduced to approximately 150 mesh and finer.

Nine patents were cited by the Patent Office, together with three publications.

Composite Glass Article. Patent No. 2,542,134. Filed July 26, 1944. Issued Feb. 20, 1951. One sheet of drawings, none reproduced. Waylande C. Gregory, inventor.

This patent discloses a method of making a decorative glass article such as a bowl. The invention is summarized in Claim 1 as follows: A composite article comprising a base with an aperture communicating with opposite sides thereof, and a glass body rigidly mounted in said aperture and forming a decorative lens, said glass body having therein haphazardly arranged internal fractures forming individually perceptible light reflecting facets imparting a gem-like quality to the lens formed thereby.

The patent contains 13 claims and 13 references.

Coil Forming Machine. Patent No. 2,545,271. Filed May 28, 1942. Issued Mar. 13, 1951. Five sheets of drawings, none reproduced. Assigned to Sylvania Electric Products Inc., by Stanley J. Gartner.

This machine forms helical glass coils, taking the glass from a molten bath and winding it upon a mandrel. The machine is mounted on rollers so that it can be moved into position over the bath. Means is provided for cooling the glass and the diameter of the coil can be changed as needed. The coil produced has very accurate dimensions in every respect including the pitch of the helix.

The patent contains 11 claims and 14 references.

HARTFORD-EMPIRE CHANGES COMPANY NAME

Stockholders of the Hartford-Empire Company have approved the management's suggestion that the company name be changed to the Emhart Manufacturing Company.

The new company title, adopted to reflect the firm's expanded and diversified operation, is effective immediately. The manufacture of glassmaking machines, with which the company has been identified since 1912, will be carried on under the previous name as the Hartford-Empire Division of Emhart Manufacturing Company. It takes its place with four other divisions and a wholly-owned subsidiary in the Emhart organization.

DR. BERNARD LONG ESTABLISHED AS CONSULTANT

Dr. Bernard Long, formerly head of the French Glass Institute and a well-known member of an international group of glass scientists, has recently established himself as an independent consultant in Paris.

Dr. Long is chief scientific adviser of the Belgian "Glaver", the French "Boussois", and the German "Delog", concerns that are all engaged in flat glass manufacture.

CORNING TO CONSTRUCT NEW GLASS PLANT IN KENTUCKY

Construction of a new glass plant in Danville, Kentucky, to provide additional facilities for the manufacture of glass bulbs and tubing, has been announced by William C. Decker, President of Corning Glass Works.

The new plant, which will have a floor area of 270,000 square feet, will be erected on a 30-acre site and construction is scheduled to begin immediately.

According to Mr. Decker's statement, the plant is being built to meet the glass bulb and specialized tubing requirements for electronic devices used in the expanding defense program. The plant will also produce bulbs and tubing used in the manufacture of incandescent lamps.

Mr. Decker explained that Danville, Kentucky, has been chosen as the location for the plant site because of its proximity to industrial consumers in the midwestern states.

W. F. CURTIS, FOSTORIA TECHNICAL DIRECTOR, DIES SUDDENLY

W. Foss Curtis, Technical Director of the Fostoria Glass Company, died suddenly from a stroke on February 20, 1951.

Mr. Curtis was first employed by Fostoria in 1913 where he worked during summer vacation. After serving in World War I, he returned to finish his formal education and, upon graduation in 1919, he entered full-time service with the company as Plant Engineer. In this capacity, he had a very active part in planning and carrying out the large plant expansion program during the late 20's and early 30's.

In 1935, Mr. Curtis was made Technical Director of the company. For many years, he had a very prominent part in the many progressive changes and developments made by Fostoria and in 1947, made an extensive trip through Europe seeking information on glass refractories and methods of production.

NEW GLASS CORPORATION FORMED ON WEST COAST

A West Coast syndicate, headed by officers of International Glass Corporation, has purchased the Hoeppner Optical Company, South Gate, California, and has financed an expansion program to develop western production of high-quality optical glass, according to Roy J. Scott, consulting engineer and President of the new corporation. Other officers are Paul Ziffren, Vice President; Max Feingold, Secretary; and Wesley R. Hauptman, Treasurer.

Roy J. Scott

The basic operation of the new corporation will be a continuation of the production of flint, crown, and very hard borosilicate glass for lenses and prisms. These general types have been produced by the Hoeppner works since 1945. In taking over the controlling stock in the Hoeppner firm, International Glass Corporation is prepared to invest the needed sums to improve production equipment, as well as to enlarge capacity at their South Gate plant which, according to Mr. Scott, is already the largest producer west of the Mississippi.

A research division has been instituted and has as its first project the development of new annealing equipment which will enable the company to produce small quantities of varying specifications on a good production basis.

Mr. Scott has been a consultant to the glass industry for many years. Since the war, he has spent a great deal of time abroad, particularly in Czechoslovakia, where a build-up in techniques and production was required following the occupation. During the war, he operated the Glass Floss Corporation.

GENERAL REFRACTORIES PLANS MAJOR EXPANSION

Plans for an approximate 12 million dollar expansion of the General Refractories Company to be completed during 1951 were announced by Floyd L. Greene, President. The first phase of the building and expansion program will begin immediately.

Included in this expansion are plans for a three million dollar plant for the manufacture of silica refractories to be constructed on the Delaware River at Morrisville, Pa. The Baltimore Works of the company is being enlarged 25 per cent and improvements and new facilities will cost $2,000,000. In addition, a new plant will be constructed in Los Angeles, which will enlarge West Coast facilities by 100 per cent.

CLIFFORD TAYLOR NAMED TO N.P.A. REFRACTORY COMMITTEE

Clifford R. Taylor, President and Treasurer of The Chas. Taylor Sons Company, has been appointed a member of the Refractory Industries Committee of the National Production Authority.

Development of Glasses Transmitting Bactericidal Radiation

The development of efficient sources of bactericidal radiation (the so-called "germicidal" lamps) using a mercury-vapor discharge enclosed either in a fused silica or in a special glass tube has created renewed interest in the subject of the transmission of glasses to ultraviolet radiation. It has long been known that fused silica transmits radiation of wavelengths as short as 1800A. This material, however, is not only expensive but in lamp manufacture requires a difficult seal-making technique owing to its low coefficient of thermal expansion compared with that of possible sealing metals, for example, tungsten and molybdenum. Again, efficient sources of bactericidal radiation utilize a mercury discharge at a low pressure, the lamp running at very nearly room temperature in contrast to the very high temperature of the high pressure lamps. It is clear, therefore, that it is desirable from an economic point of view for germicidal lamps to be made from glasses other than fused quartz, provided they transmit efficiently the resonance wavelength (2537A.) of the low pressure mercury discharge.

Only two suitable types of glass have been made for these lamps; one known as "Pyrex" brand glass No. 9741, and the other as Vycor brand glass No. 791. Both glasses and their seals to metal are necessarily somewhat expensive so that it is obviously advantageous if suitable "soft" glasses can be made with good transmission to 2537A. radiation and with expansion coefficients similar to those of the common soda-lime-silica glasses used in the lamp and valve industry.

Soda-lime-silica glasses transmitting long-wavelength ultraviolet light have long been known, but the commercial glasses used hitherto have had zero transmission at approximate 2537A. Little systematic work has been done on the effect of chemical composition in this region of wavelength, but it is already known that traces of iron, present in glasses as an impurity, have a marked effect on absorption in the short ultraviolet region. It has been shown that iron in the ferrous condition is less harmful than iron in the ferric condition. For example, in a glass of percentage composition SiO_2 75, CaO 10, Na_2O 15, 0.01 per cent of iron oxide, present in the reduced state, showed a complete absorption at 2650A. With the same percentage iron content, but practically all in the ferric condition, the same glass cut off at 2675A.

It would appear from the above that an ordinary soft soda-lime-silica glass has zero transmission for the 2537A. line if it contains as much as 0.01 per cent of iron oxide even in the reduced state. It is obviously very difficult to produce glasses on a large commercial scale with iron oxide content below 0.01 per cent so that the chances of developing commercial glasses having the necessary qualifications for germicidal lamp use seem very remote.

That such glasses are possible to produce is shown by the work reported by J. E. Stanworth in the August 1950 issue of the *Journal of the Society of Glass Technology*. At the beginning of the work it was decided first of all to determine the ultraviolet transmission of pure glasses made by using raw materials which it was expected would be obtainable in a pure state on a large commercial scale. Lead oxide was avoided as it was known that this oxide has a strong absorption in the ultraviolet region. Accordingly, silicate glasses containing large percentages of barium oxide were studied first. The only other requirements of the composition were that the glass should melt easily at about 1400°C. and should have good working properties, both in forming to shape in the glassworks and in the production of lamps. These factors led to the choice of a glass of percentage composition: SiO_2 65, B_2O_3 2, Na_2O 5.5, K_2O 9.5, BaO 18, made from a batch consisting of ground quartz 65, dehydrated borax 2.9, soda ash 7.6, dehydrated potassium carbonate 13.9, barium carbonate 23.2. This glass contained about 0.01 per cent iron expressed as Fe_2O_3, the iron being reduced to the ferrous state by the addition of aluminum powder to the batch. This glass met all of the requirements for a satisfactory germicidal glass. However, sulphates present as impurities in the raw materials (for example, in the barium carbonate) or deliberately added for refining purposes reduced the ultraviolet transmission of the glass, and small amounts of titania present as an impurity in many sands were also harmful.

A soda-lime-silica glass of percentage composition SiO_2 75, CaO 10, Na_2O 15 also transmitted well at 2537A. even when it contained about 0.01 per cent iron oxides reduced by the addition of aluminum, in contrast to the earlier findings of D. Starkie and W. E. S. Turner who failed to obtain transmission at such short wavelengths in a glass of the same composition. It seems probable that this difference can be explained by the more efficient reduction of the iron to the ferrous state in the Stanworth glass and to the greater purity of the raw materials with regard to sulphur and possibly other deleterious elements. Changes of basicity or of soda-potash ratio within the limits studied had a negligible effect on the ultraviolet transmission.

The results on these rather complicated glasses emphasized the importance of impurities and provided little support for the view that the main glass constituents themselves have much influence upon the ultraviolet transmission properties. (That is, within the limited field studied. There is no doubt that certain oxides, for example PbO, absorb strongly.) In order to provide further evidence on the question of the effect of structural factors, a series of melts was undertaken in the simple system Na_2O-B_2O_3.

Melts in the Na_2O–B_2O_3 system showed that the transmission to 2537A. decreased with increase in the Na_2O content, but the transmission of any particular glass depended markedly on the type of raw materials used in its preparation. Melts made using borax were superior to those using sodium carbonate as the source of the Na_2O, and the addition of a small percentage of aluminum powder to the batch also improved the trans-

(*Continued on page* 208)

THE O. HOMMEL COMPANY OBSERVES ITS SIXTIETH YEAR

Entering into its 61st year as a leading manufacturer and supplier to the ceramic industry, The O. Hommel Company looks back upon sixty years of steady progress and development which has continued despite the hardships of war and complete destruction by fire in 1916.

Ernest M. Hommel

Oscar Hommel, founder of the company, began operations near the turn of the century in a small building, serving as both factory and office, with a staff of three persons. During its infancy, the company concentrated on the importation of bronze powders. By 1903, The O. Hommel Company had expanded into newer and broader fields. New products were being manufactured and more equipment was put into operation. As the demand for ceramic colors increased, further expansion was necessary until, in 1905, the company moved to Fourth Street and Duquesne Way in downtown Pittsburgh.

In 1916, the expanding company faced oblivion when lightning struck its plant, followed by an uncontrollable fire and complete destruction. All the stocks of material were lost and the machinery damaged beyond repair. Replacement of any machine parts from Europe was out of the question since the world was then in the throes of World War I. Still, through the perseverance of Mr. Hommel, reconstruction of the plant began, new machinery installed, and the firm went on to further expansion and wider activities.

Today, 60 years after its beginning, The O. Hommel Company has also developed a world-wide market. Aside from complete representation in the United States, Hommel sales representatives are established in Belgium, France, Luxemburg, Netherlands, South Africa, Argentina, Uruguay, Brazil, Mexico, Spain, and Sweden. Direct selling is done to glass, pottery, porcelain enameling companies throughout the rest of the world. In England, an associate company manufactures porcelain enamel frit. O. Hommel Company's Industrial Sales Department also represents the leading manufacturers of industrial chemicals in the tri-state area.

Through the years, The O. Hommel Company has attracted to its staff some of the country's recognized experts in the ceramic and chemical fields. E. M. Hommel, President, has been intimately associated with the company's problems for over 26 years. H. R. Urbach, General Manager and Treasurer, has been with the company for 48 years and is also well known in all phases of the ceramic industry. Other old-time associates are W. T. Campbell, Secretary; J. F. McCrory, Manager of the Chemical Resale Division; J. H. Sylvester, Plant Superintendent; and J. H. Clatty, who takes the responsibility for frit manufacturing. Over 25 per cent of the employees have been with the company for 10 years or longer.

Since its inception, the company has always believed that research is closely allied to progress. As a result, many valuable contributions have been made to the ceramic industry. In the equipment field of the industry, The O. Hommel Company is credited with a "first". The company was the only manufacturer supplying spray guns to the industry as long ago as 1903.

There was also the development of silk screen colors for glass by the squeegee process, another feather in the cap of Hommel engineers. A more recent achievement in the squeegee process field is the perfecting of "hot screening" methods. O. Hommel Company's technological advances in hot screening methods have opened up entirely new fields for glass and pottery decoration.

Further laurels can be added when the company's pioneering work on alkali and acid resisting colors for beverage bottles and glass tableware is considered. The company's research on titanium white frits, which was started in the early 1920's under the direction of W. E. Dougherty, culminated in the issuance of a patent in 1933 and resulted in another notable advance within the industry.

Although the company has always maintained its own research and development laboratories, Oscar Hommel augmented these facilities by establishing at Mellon Institute in 1933 a Research Fellowship which, since 1940 has had as its Senior Fellow, Dr. E. E. Marbaker.

Still looking to new horizons, Ernest M. Hommel, son of the founder and President since 1940, outlines the policy of the company in an excerpt from an open letter to the ceramic industry. "Through constant research, both at our plant and at Mellon Institute, we are exerting every effort to make our products the best in the ceramic industry. This diligent perseverance and progress in research has helped our company produce materials that meet highest standards. We pledge a continuance of this policy."

L-O-F FORMS NEW DIVISION TO MANUFACTURE FIBER GLASS

John D. Biggers, President of Libbey-Owens-Ford Glass Company, has announced the formation of a new division of the company for the manufacture of fiber glass. The new division will occupy the company's Parkersburg, W. Va. factory with more than 200,000 square feet of floor space. Equipment of the Parkersburg plant will be rushed so that production may be underway in approximately six months.

A certificate of necessity has been issued by the United States Government for development of this new business to aid in the national defense rearmament program. A license agreement has been negotiated with Owens-Corning Fiberglas Corporation to use its patents and processes for making textile and superfine fiber glass, supplemented by an engineering agreement covering technical and engineering assistance.

The new Fiber Glass Division of L-O-F will be under the general direction of G. P. MacNichol, Jr., Vice President of the firm. However, Robert E. Worden, of Worden & Risberg, consulting management engineers and industrial managers, will serve as General Manager during its development. Donald L. McClure, associated with glass operations at Rossford, Ohio, plant for 15 years, will be the Factory Manager.

Current Statistical Position of Glass

Employment and payrolls: During the month of January 1951, employment in the glass industry was reported at a preliminary 127,700 persons. Compared with the adjusted figure of 127,600 for December 1950, this indicates only an increase of 100 persons. During January 1950, employment had been 105,700, or close to 21 per cent below January this year.

Payrolls for January were reported at a preliminary $36,599,671. The adjusted December 1950 payroll figure of $36,255,839 indicates an increase of close to 1 per cent paid out by glass manufacturers during January. Payrolls during January 1950 were $26,987,324, which is about 35 per cent below January 1951.

GLASS CONTAINER SHIPMENTS

(All figures in Gross)

Narrow Neck Containers	February 1951
Foods	930,605
Medicinal & Health Supplies	1,185,451
Chemicals, Household & Industrial	608,047
Beverages, Returnable	334,786
Beverages, Non-returnable	10,656
Beer, Returnable	225,885
Beer, Non-returnable	314,774
Liquors	1,142,343
Wines	282,589
Toiletries & Cosmetics	557,738
Sub-total (Narrow)	5,592,874
Wide Mouth Containers	
Foods	2,004,773
Dairy Products	285,317
Home Canning	*
Medicinal & Health Supplies	322,553
Chemicals, Household & Industrial	116,044
Toiletries & Cosmetics	117,225
Packers' Tumblers	124,673
Sub-total (Wide)	2,970,585
Total Domestic	8,563,459
Export Shipments	208,382
TOTAL SHIPMENTS	8,771,841

* This figure included with Wide Mouth, Foods.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in Gross)

		Production February 1951	Stocks February 1951
Foods; Medicinal & Health Supplies; Chemicals, Household & Industrial; Toiletries and Cosmetics	Narrow Neck	3,596,294	2,941,678
	Wide Mouth	2,737,680	2,629,175
Dairy Products		302,798	301,591
Home Canning		*	*
Beverages, Returnable		400,326	516,635
Beverages, Non-returnable		8,561	21,427
Beer, Returnable		308,394	220,879
Beer, Non-returnable		275,901	167,396
Liquors		1,154,867	432,250
Wines		297,379	291,986
Packers' Tumblers		118,422	108,462
TOTAL		9,200,622	7,631,479

* This figure included with Wide Mouth Foods.

Glass container production and shipments, based on figures released by the Bureau of Census, fell off somewhat during February. Part of this slack, however, can undoubtedly be laid at the door of the annual February shortage of days. In any event, production and shipments are still well ahead of February 1950.

During February, glass container manufacturers produced 9,200,622 gross. This is 10 per cent less than January production, which was 10,278,883 gross. During February 1950, production was 7,349,569 gross, or 25 per cent below February this year. Total glass container production for January and February 1951 has reached 19,479,505 gross. Compared with the 15,284,068 gross produced during the corresponding period in 1950, production during 1951 is thus far running close to 27½ per cent ahead of 1950.

Shipments of glass containers during February were 8,771,841 gross. Shipments during January were 9,719,684 gross, or about 9½ per cent more than for February. During February 1950, shipments were 6,899,588 gross, or 27 per cent less than for February 1951. Total shipments at the close of the first two months of 1951 have reached 18,491,525 gross, which indicates that 1951 shipments are 27½ per cent ahead of the same period in 1950 when shipments were 14,489,721 gross.

Stock on hand at the close of February were 7,631,479 gross, or a little higher than the 7,286,483 gross on hand at the end of January. Stocks at the close of February 1950 were 9,693,904 gross.

Automatic tumbler production during February 1951 was reported to be 6,506,152 dozens. This represents a drop of 6½ per cent from the 6,959,061 dozens produced during January. During February 1950, production was 5,577,795 dozens. Shipments for February also dropped off and were 6,132,451 dozens—a little more than 10 per cent less than the 6,831,437 dozens shipped during January. Shipments during February 1950 were 5,551,844 dozens. Stocks on hand at the close of February were 9,939,675 dozens, which is 3½ per cent more than at the close of January when stocks were 9,601,931 dozens. At the close of February 1950, stocks were 9,819,907 dozens.

Table, kitchen, and household glassware: Manufacturers' sales of machine-made table, kitchen, and household glassware during February 1951 were 3,364,357 dozens. This is a little more than 8 per cent below the previous month's sales of 3,666,519 dozens. During February 1950, sales were 3,178,658 dozens. Total manufacturers' sales at the close of the 12-month period ending February 1951 were 40,641,001 dozens. Compared with the 39,037,183 dozens sold during the corresponding period in 1950, an increase of 4 per cent is indicated.

• George S. Hamilton, Vice President and Comptroller of Innis, Speiden & Company, has been elected to the additional office of Treasurer, according to an announcement by William H. Sheffield, Jr., President, following a meeting of the Board of Directors.

New Equipment and Supplies

NEW PATENTED BUSHINGS

Norton Company, Worcester, Mass., is manufacturing its latest development in grinding wheel manufacture. The company states that its new patented bushings, which are pressed into the wheel, have several distinct advantages over poured lead bushings which have been standard practice for many years.

The light-weight of the new bushing and its uniformity of size preserve the inherent balance of wheels made by Norton's new manufacturing process. The new precision bushing maintains more consistent hole size from wheel to wheel with consequent advantages of uniform mounting conditions for the user. The press fit method of mounting the bushing insures greater holding power of the bushing within the wheel.

NEW TRUCK-TABLE COMBINATION

Rol-Away Truck Company, 2340 Columbia Blvd., Portland 17, Oregon, has announced its new Rol-Away Model A W L which serves either as a one-man truck or as a sturdy work table. The truck, which is specially designed to handle flat cases of glass, sheet metal, or other flat material, rolls easily in any direction. By tipping the truck back, it makes a sturdy platform table for packing or unpacking cases.

The new truck can be easily operated by one man for packing, loading, hauling, or unloading. It eliminates the need for placing packing cases on the floor, which is a difficult position from which to work. Sheets or cases can be slid onto the platform from piles, then wheeled to other areas and unloaded to other stacks, onto trucks or distributed piece by piece.

NEW UMBRELLA STIRRER

Fisher Scientific Company, 717 Forbes Street, Pittsburgh 19, Pa., has developed a new Umbrella Stirrer in an effort to solve the problem of inserting four-inch stirrer-propellors through narrow-necked flasks and similar vessels.

The stirrer, which has four blades that can be closed to pass through the neck of the flask and then opened for maximum stirring effectiveness, speeds up dissolving action, preparation of slurries, mixing of emulsions, etc. It is particularly valuable for use with a 3-neck flask when a minimum of exposure to air is desirable. The 12-inch shaft of the stirrer fits into chucks of any motor device accommodating ¼-inch rods. All parts of the stirrer are made of corrosion-resistant stainless steel.

AUTOMATIC HIGH-SPEED AMPUL PRINTER

Ceragraphic, Inc., 250 South Street, Newark 5, New Jersey, has announced the manufacture of what it states is the first Cera-fuse Automatic High-Speed Ampul Printer ever to be put into practical operation.

The new ampul printer enables a drug or allied manufacturer to print automatically, economically, quickly, permanently, and colorfully on glass ampuls in his own plant. It makes possible mass production printing on ampuls, vials, carpuls, glass rods, glass droppers, and miscellaneous glass tubes.

The new equipment is made up of two units: a fully automatic, one-color, silk screen printing unit and a small, efficient conveyor furnace. The 1100°F. temperature fuses the ceramic enamel permanently to the surface of the glass. The new Cera-fuse process, the company states, insures protection against such sterilizing processes as steam, autoclave, Bard-Parker solution, Zephiran Chloride, alcohol, etc.

The entire printing process, consisting of feeding stock to the machine, inking, and inspecting, requires only one operator and produces at least 3,000 to 5,000 ampuls an hour. The machine can be easily adjusted in less than half an hour to print on any ampul, 25 or 30mm to 150mm in length.

CATALOGS RECEIVED

Leeds & Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa., is distributing a folder describing new equipment for glass feeder temperature control.

The 8-page folder, "Stabilize Glass Feeder Temperatures", describes how precise, automatic control of glass feeder temperature is producing increased savings in material and time and reducing the time required for job changes by as much as one-third.

The folder describes for the first time the application of Speedomax Control to the feeder process, and details the special features included to assure unusual temperature stability. Sketches show the location and installation of primary elements in the feeder, and a schematic diagram relates the units of the Speedomax Electric Control system to the detection and control sequence. A complete listing of equipment for both electric and pneumatic control is given.

Cambridge Wire Cloth Company, Cambridge, Maryland, is distributing its Bulletin 99 which is devoted to the designing aspects of the firm's facilities, and the craftsmanship involved in the fabrication of these designs.

The folder graphically illustrates the processes involved from the draftsman's table through to the finished product with brief descriptive material touching on the steps passed through.

Laclede-Christy Company, 3600 Forbes Street, Pittsburgh 13, Pa., has issued a new folder featuring the company's Cast 400 Tank Block.

The four-page folder illustrates and describes the history and outstanding features of Cast 400 block. A discussion of refractory upperstructure materials is included with descriptive material concerning Mix 6, Mix 89, and Mix 257. The fourth page of the folder is devoted to glass refractory specials. Floaters and debiteuse are described and illustrated, as well as pots and pot furnace specials and feeder parts.

Fish-Schurman Corporation, 230 East 45th Street, New York 17, New York, has issued a new bulletin devoted to "Steelset" impregnated diamond wheels and tools.

The booklet is profusely illustrated with cut-away line drawings and numerous tables giving particular specifications. Covered in the bulletin are Lens Generating Wheels, FS Central Coolant Feeds for Wet Drilling, Standard, Bayonet, and Large Coolant Feeds, Disintegrating-Core Drills, Mounted Points, and Wheels of various designations.

The Bristol Company, Waterbury 20, Conn., has just published a new edition of its thermocouple and pyrometer accessories bulletin listing many additional items and containing new data on the proper application and use of thermocouples.

The new 56-page bulletin contains a well illustrated catalog of hundreds of pyrometer supply items, including assembled thermocouples, thermocouple wires, extension wires, protection tubes, insulators, and accessories for the full range of industrial pyrometer applications.

New technical information and installation sketches have been added to the "Users' Manual" section, which contains engineering data on modern practices in pyrometry. Also included are tables of calibration data for the commonly-used base metal and rare metal thermocouples.

Fischer & Porter Company, 4030 County Line Road, Hatboro, Pa., has issued a new catalog describing Viscorator instruments that provide an instantaneous method for determining viscosity values for industrial processes.

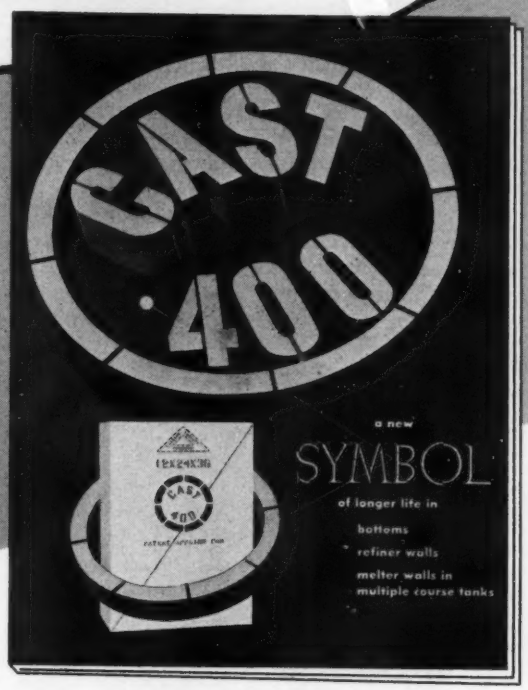
Featured in Catalog 88 is a new development in the field represented by the Auto-Sampling Viscorator instrument which has a constant differential pressure regulator as an integral part of its design. This provides a constant meter sample flow rate (regardless of line fluctuations) in a simple self-contained unit.

Patterson-Kelley Co., Inc., 74 Warren Street, East Stroudsburg, Pa., has just issued a four-page condensed catalog showing representative items in its line of heat transfer equipment, blenders and process vessels, such as kettles, mixers, etc.

New Bulletin*

about a

new tank block



Here is a new bulletin that summarizes important facts about the development and application of an entirely new block for glass tank bottoms, refiner walls and melter walls in multiple course glass tanks.

One section shows test results of this new block as compared with conventional materials—why CAST 400 gives a pronounced increase in service life.

Other data on refractory upperstructure materials tells how and where each of three grades of upperstructure refractories may most efficiently and economically be used.

A summary on glass refractory specials reviews floaters and debiteuse, pots and pot furnace specials, boots or bootlegs, and feeder parts.

* *Glass tank designers and operators who want this reference bulletin may have it upon request. Write for it today.*

Cast 400 Tank Blocks • Upperstructure Refractories • Glass House Specials • Pots, Firebrick and Cement • Silica Brick

One dependable source for every refractory you need

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Quality First

Glass Refractory Manufacturing Plants:
St. Louis, Mo. • Toledo, Ohio • Warm Springs, Calif.

(*Continued from page* 174)

ing "rising" or "falling" color, one determines whether one is dealing with compression or tension along the sample axis; conventionally, compressions are denoted +, tensions —.

The present authors call the *polarimetric curve of a glass-metal pair* the representative curve of measured path differences of a sample type B as a function of temperature in a given cooling program. The starting point, which shall be correlated in the second part of this study with the thermal characteristics of the glass, corresponds to a strain free condition.

It should be stated now that: (1) All curves remain identical when repeated on the same samples for the same cycles. (2) All curves utilized in this study have been traced for samples of different shape and identical glass-metal parts, starting at the same initial temperature, the annealing temperature, T_r. (3) For all glass-metal pairs, the cooling process was conducted by a program controller at the uniform rate of 3° per minute.

The curves are given in the lower part of Figs. 19, 20, 21.

Correspondence of Polarimetric and Dilatometric Experiments

Qualitative Correspondence.

In Figs. 19, 20, 21 have been plotted, for three different glass-metal pairs: (a) The differential expansion curves, (b) The polarimetric curves, for sample type B.

Danzin[2] and Danzin and Vallentin[10] have shown that the polarimetric curves can be deduced qualitatively from the absolute dilatometric curves, by a translation along the axis of elongations of the dilatation curve of the glass until it cuts the dilatation curve of the metal at a temperature equal to the initial temperature of the polarimetric curve (which is the practical annealing temperature of the glass). This observation is only qualitatively true. It renders the general appearance of the phenomenon but does not allow the establishment of an exact relation between strain free points. In a later article one will find that the points of zero strain are a function of the relaxation phenomenon in the annealing range, as a consequence of all sealing variables.

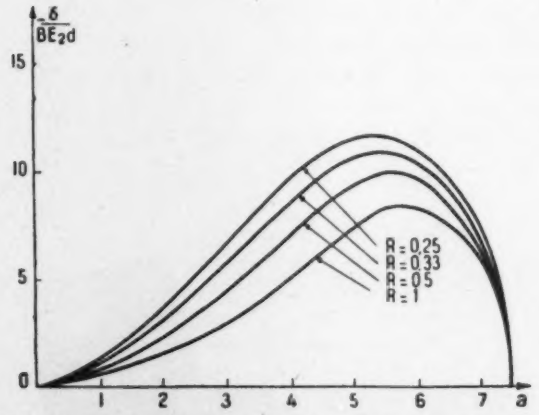

Fig. 15. Sample type A (cylindrical seal). Graphic representation of birefringence along a ray perpendicular to the axis and tangential to the metal calculated by Poritzky's approximation.
in millimicrons/kg/mm²/mm E₂ in kg/mm² d in mm/mm (negative).

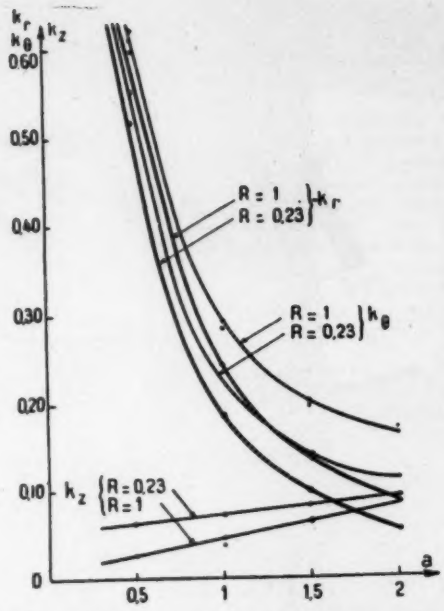

Fig. 16. Sample type A. Variation of the path difference — maximum strain correspondence coefficients with metal radius a for R (ratio of modules E_2 (glass) : E_1 (metal) = .25, .33, .5, 1

Nevertheless, the analogy of the polarimetric and dilatometric curves can be observed, particularly in a rectilinear portion. This is indicative of the proportionality of the path differences to the dilatation differences in the elasticity range.

Quantitative Correspondence in the Elastic Range.

In the case of sample type A, it was shown that theoretical correlations can be derived easily but are not easily verified experimentally because of the difficulty to follow the temperature change of the path difference. The strain distribution according to Poritzky, Hull and Burger has been verified by many authors[11].

In the sample type B, the examination of: (a) The dilatometric curves (differential glass metal) of Fig. 4 and, (b) The polarimetric curves for a = .5, 1, 1.5, 2 for each glass-metal pair of Figs. 19, 20, 21, corresponding to the data of Table 4 shows that the path difference can be expressed as:

$\delta / BE_2d = -K(a - a_o)$; K and $a_o = f(R)$ (see Fig. 22.)

This relation evidences the proportionality of the path difference with: (a) The difference in dilatation between glass and metal, (b) The Brewster constant of the glass, (c) The elasticity module of the glass, (d) a function of the diameter of the metal and the Young module ratio.

Fig. 23 gives K and a_o as functions of R.

The Relation of Path Difference and Maximum Strain in Sample Type B.

For samples of type B, the hypothesis can be made that the maximum strain follows the metal interface along the diameter perpendicular to the large faces. This

(*Continued on page* 194)

Specify THREE ELEPHANT BORAX AND BORIC ACID

Plant of American Potash & Chemical Corporation, Trona, California

The use of borax in commercial soda-lime-silica glasses has become standard practice during the past few years.

It facilitates the melting process to an extent which is apparent in lower production costs. In a properly balanced batch, borax will improve the strength, color, brilliancy, thermal properties and durability of your product.

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(*Continued from page* 192)

hypothesis is supported by the location in a diametrical plane parallel to the large faces of experimental failure. It also can be assumed that the amount of these strains is equal to those in samples type (A) with the following geometry:

$$a_A = a_B;\ b_A = e_B = 3.5$$

Then one may calculate, like in the case of A:

(p_r/E_2d) max, (p_θ/E_2d) max, (p_z/E_2d) max $= f_1$ (a, R) and having determined $\delta/BE_2d = -K(a - a_o)$, one may again define for this sample correspondence coefficients so that:

$$(p_r)\ \max = K_r\,\delta/B$$
$$(p_\theta)\ \max = K_\theta\,\delta/B$$
$$(p_z)\ \max = K_z\,\delta/B$$

which are tabulated in Table 5 as functions of a and R, and plotted in Fig. 24.

As in the case of samples type A, it should be noted that: (1) The maximum strains are proportional to δ (path difference), (2) The maximum strains are inversely proportional to B (Brewster coefficient), (3) To small values of δ correspond small p_z, but larger p_r and p_θ, e.g. $p_\theta/p_z \sim 2$ for $a = 2$, $p_\theta/p_z \sim 8$ for $a = .5$.

Accessory Tests

Measurement of Young Module.

(a) of metals and alloys (E_1). The measurement is made by a traction test on a Chevenard micromachine. The values of E_1 for the materials used are listed in Table 4. In the temperature range of interest in this study the variations of E_1 have been neglected.

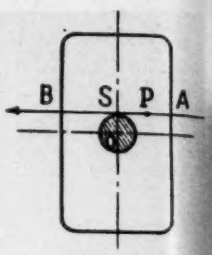


Fig. 17. Sample type B. Birefringence along a ray perpendicular to large faces and tangential to the metal.

(b) of glasses (E_2). The measurements were carried out in the Glass Institute by the method described by Cabarat[12]. The studies of Cabarat, and of Gillod[5] show the variations of this module with temperature and original quenching state.

In the elastic range which is considered here, the temperature variation was neglected and annealed values were used (maximum error 10%).

The values of modules E_2 of glasses used in this study are indicated in Table 4. Another method for the determination of this module is under investigation.

Poisson's Module.

The value $\sigma = .3$ was used for glass and metals, as was done by Hull and Burger[7] (maximum error 2%).

The Measurement of the Brewster Coefficient of Glasses[13].

These measurements are effectuated by means of the apparatus described schematically by Fig. 25.

Two samples—one known, one unknown—of equal cross-section are submitted to the same axial stress. The measurement of the path differences permits the deter-

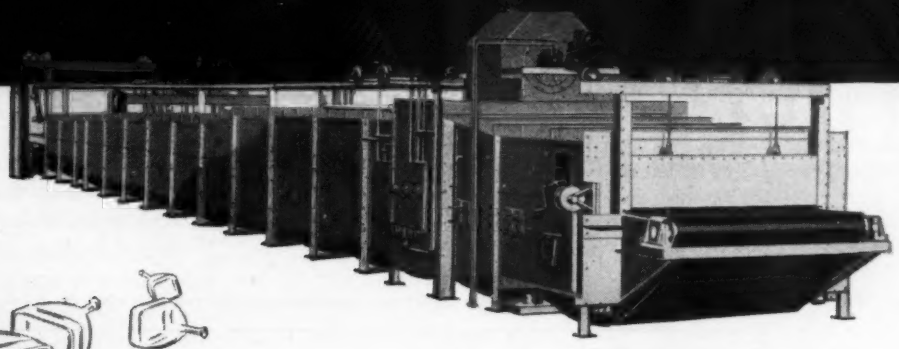
(*Continued on page* 196)

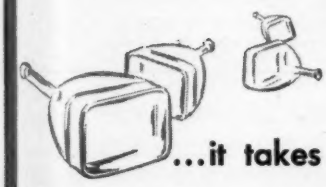
Table 4

Sample type B (Fig. 8). Experimental δ/BE_2d (path difference : Brewster's coefficient X glass module X contraction) for three glass metal pairs.

Glass-Metal Pair	d^{T}_{20} $\times 10^3$	$a = 2$		$a = 1.5$		$a = 1$		$a = 0.5$		T
		$-\delta^{T}_{20}$	$\frac{-\delta}{BE_2d}$	$-\delta^{T}_{20}$	$\frac{-\delta}{BE_2d}$	$-\delta^{T}_{20}$	$\frac{-\delta}{BE_2d}$	$-\delta^{T}_{20}$	$\frac{-\delta}{BE_2d}$	
L621 Dilver P	0.126	132	5.75	85	3.7	64	2.8	26	1.13	100
$E_1 = 6250$ kg/mm²	0.140	159	6.2	108	4.2	74	2.9	38	1.48	150
$E_2 = 5620$ —	0.120	123	5.6	93	4.25	64	2.9	26	1.18	200
$R = E_2/E_1 = 0.90$	0.081	89	6	60	4.05	44	2.95	18	1.22	250
$B = 32.5$ mμ/kg/mm²/mm										
A. 119 Molybdène	$d/^\circ$ $\times 10^7$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	
$E_1 = 28400$ kg/mm²										
$E^2 = 6570$ —										
$R = E_2/E_1 = 0.23$										
—1841	4.05	0.620	8.5	0.508	7	0.341	4.65	0.110	1.5	
$B = 27.5$ mμ/kg/mm²/mm —2068	4.70	0.705	8.3	0.575	6.75	0.292	3.43	0.086	0.96	
Télévic Ferrochrome	$d/^\circ$ $\times 10^7$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	$-\delta/^\circ$	$\frac{-\delta}{BE_2d}$	
$E_1 = 5950$ kg/mm²										
$E_2 = 6120$ —										
$R = E_2/E_1 = 1.03$										
$B = 21$ mμ/kg/mm²/mm	14.7	1.17	6.15	0.84	4.45	0.593	3.12	0.173	0.920	

IN THE TV INDUSTRY





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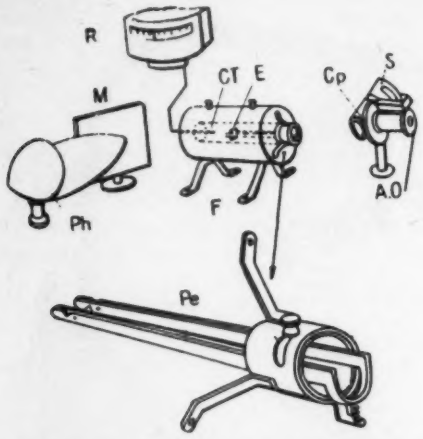


Fig. 18. Polarimetrical Assembly (schematically)

R	**Program Controller**	**E**	**Sample**
M	**Polarizing Mirror**	**Pe**	**Sample Carrier**
Ph	**Light Source**	**Cp**	**Compensator**
F	**Furnace**	**S**	**Graduated sector of CP**
CT	**Thermocouple**	**AO**	**Analyzer Ocular.**

mination of the B of the unknown from that of two known standards.

Winter-Klein has shown[14] that the Brewster coefficient B varies with temperature, but has not separated the effect of temperature and of heat treatment. In the elasticity range, which alone was considered, B was assumed constant.

The values of B of the glasses used in this study are indicated in Table 4.

Note.

The verification of the linearity of δ as a function of d shows that the approximation based on the assumed constancy of B, E_1, E_2 with temperature gives satisfactorv results.

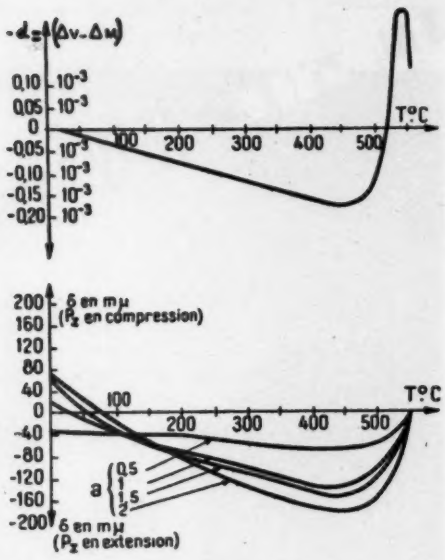


Fig. 19. Molybdenum — Glass A 119-1841 Seal. Type B (Fig. 8). Comparison of differential dilatometry (annealed glass) (upper curve) and polarimetry (lower curve) in the so-called elastic temperature range.

Application of Dilatometric and Polarometric Tests

Dilatometric Tests.

The dilatometric tests can only take account of the relaxation produced in the glass, different from that originating as the consequence of differential contraction in a seal. The absolute or differential dilatometric tests therefore permit only attaining strain variations produced by homogeneous temperature variation in glass and metal within that temperature range in which the glass is to be considered a perfectly elastic solid. They cannot teach anything about strains existing in the seal at any given temperature. (Later, the authors will show that the zero

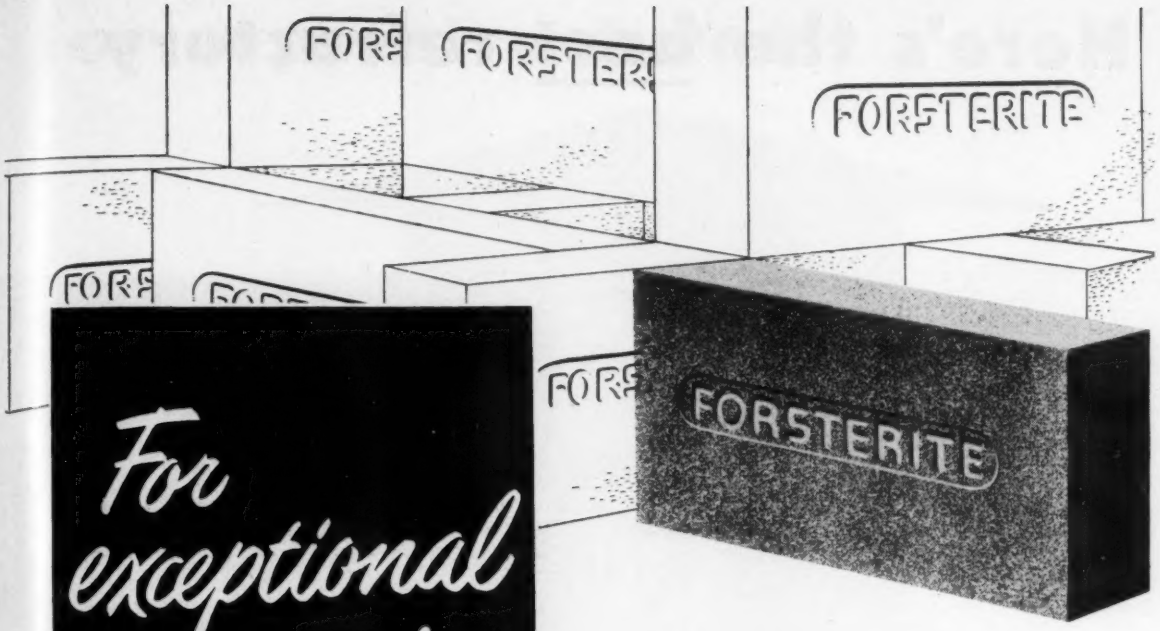
(*Continued on page* 200)

Table 5

Sample type B (Fig. 8). Maximum strain — path difference correspondence coefficients : K_r $K\theta$ K_z.

a	R	$\left(\frac{p_r}{E_2 d}\right)$max.	$-\left(\frac{p_\theta}{E_2 d}\right)$max.	$-\left(\frac{p_z}{E_2 d}\right)$max.	$\frac{\delta}{BE_2 d}$	$-K_r$	K_θ	K_z
0.5	1.03	0.70	0.73	0.030	1.2	0.585	0.61	0.0250
	0.90	0.72	0.76	0.032	1.2	0.600	0.63	0.0266
	0.23	0.88	0.94	0.110	1.7	0.516	0.55	0.0645
1	1.03	0.65	0.78	0.105	2.7	0.241	0.288	0.0390
	0.90	0.67	0.80	0.125	2.7	0.248	0.296	0.0465
	0.23	0.83	0.98	0.320	4.5	0.184	0.217	0.0710
1.5	1.03	0.58	0.85	0.24	4.3	0.135	0.197	0.056
	0.90	0.60	0.88	0.27	4.3	0.139	0.204	0.063
	0.23	0.78	1.03	0.58	7.2	0.100	0.143	0.0855
2	1.03	0.47	0.95	0.49	5.8	0.0810	0.163	0.0845
	0.90	0.49	0.97	0.53	5.8	0.0845	0.167	0.091
	0.23	0.57	1.10	0.83	10	0.057	0.110	0.083
		×	+	+	+	×		

\+ Theoretical.
× Experimental.



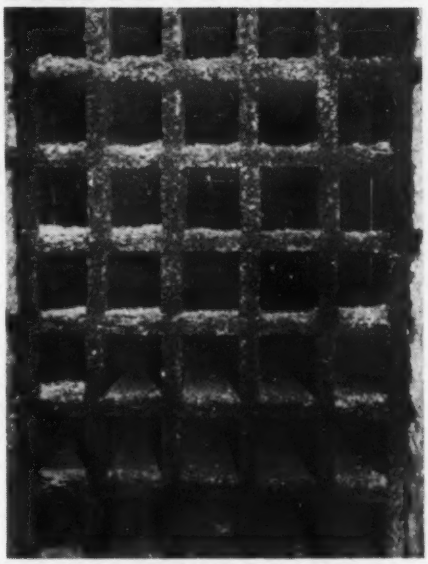
For exceptional service

in glass furnace regenerators

HARBISON-WALKER FORSTERITE REFRACTORIES

A service life of several years, while exceptional with most checker brick, is not uncommon with Harbison-Walker FORSTERITE. This hard burned magnesium-silicate refractory is extremely resistant to wetting and slagging at high temperatures.

Forsterite checkers used in full height air-chamber settings remain clean, dry and highly efficient, because they withstand fluxing by volatile alkalies and batch carry-over without wetting, glazing or clogging. In regenerator side walls, arches and in port walls and crowns Forsterite refractories are also used with excellent results.



The clean condition of this glass furnace regenerator checker setting of Harbison-Walker Forsterite brick after 18 months of continuous service is typical of many installations.

HARBISON-WALKER

REFRACTORIES COMPANY *and Subsidiaries*

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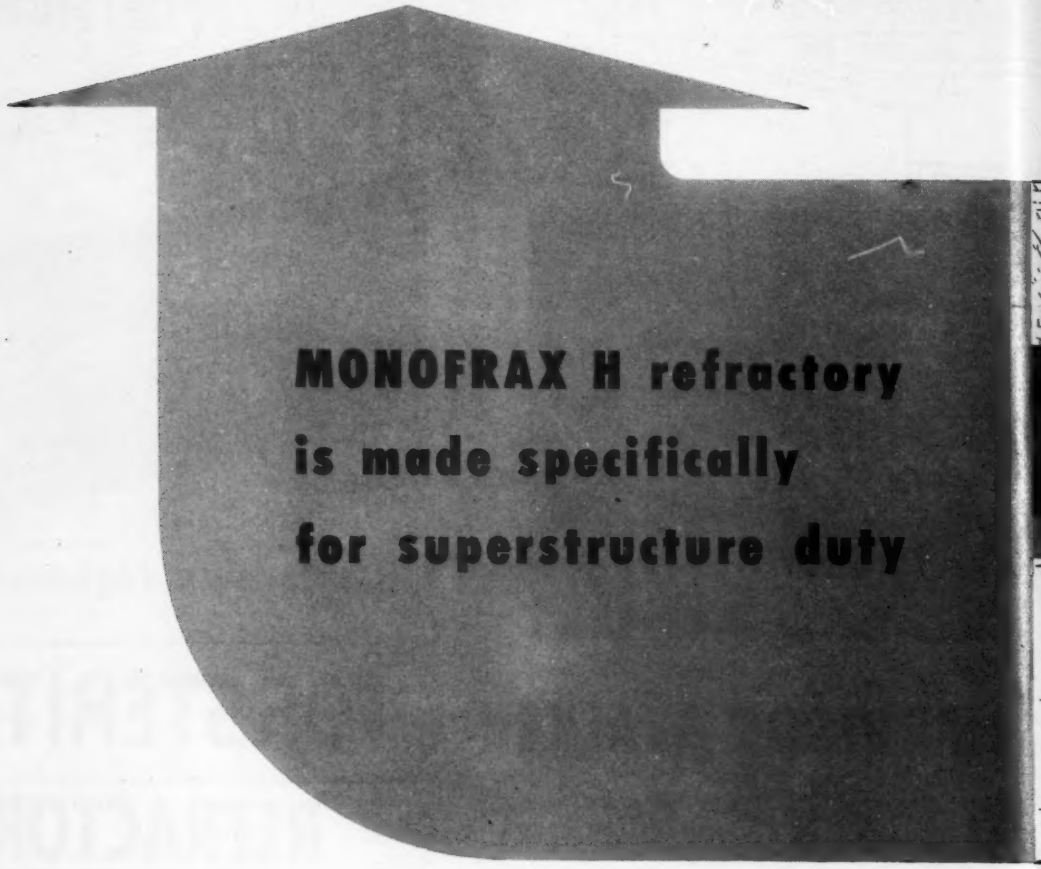
WORLD'S LARGEST PRODUCER OF REFRACTORIES

Here's the best refractory



With tank blocks lasting considerably longer, operators are finding it advisable to get top-rate superstructure refractories—refractories that will match the increase in life of the tank proper.

MONOFRAX H fused cast refractory is a special-purpose material designed to withstand the very conditions which superstructures must meet. You'll find that not only does it deliver maximum superstructure life but also helps to improve the quality of your glass.

Chemically inert

Because of the unusual chemical inertness and refractoriness of beta alumina, MONOFRAX H refractories prevent eutectic formations with other refractories, volatilized alkalies, and batch dust. No appreciable formations develop when it is placed either next to, or below, other commercially available refractories.

Blocks set easily, fit snugly

Careful and skilled workmanship is a plus value of all MONOFRAX H blocks. You'll find that they lay up quickly and easily—make smooth, tight-fitting joints.

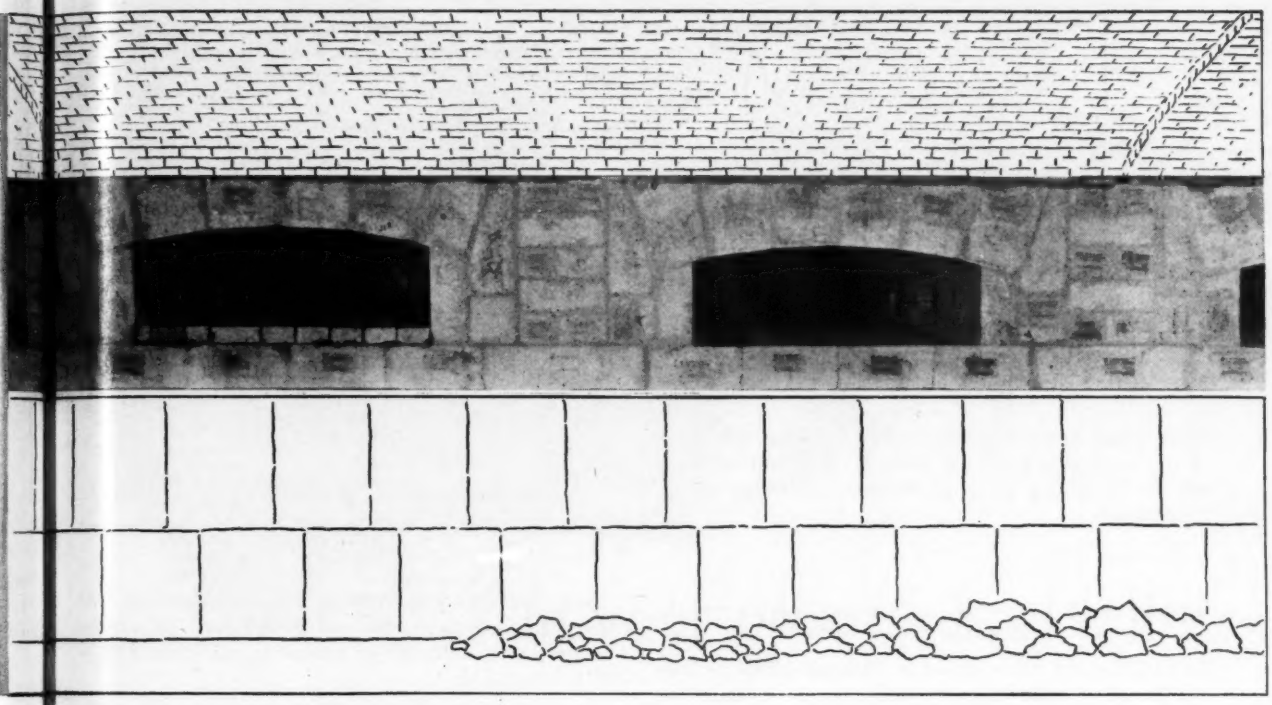
Minimizes dripping

The nearly pure alumina content of MONOFRAX H refractory gives this material a refractoriness that practically eliminates all dripping. Moreover, since this material contains less than 0.5% glassy matrix there is negligible "honey-combing" of the refractory face. In other refractories with a higher percentage of interstitial glass, this glassy matrix is often leached out by the furnace atmosphere leaving a "honey-combed" refractory face that is prone to spall.

High resistance to heat shock

MONOFRAX H material is not only resistant to extreme heat—being safe up to 3450°F—but it can also withstand the repeated shock of fluctuating temperatures. It has a fairly open crystalline structure that permits the

for superstructures



particles to expand and contract slightly without introducing undue stresses. As a result, MONOFRAX H material has superior stamina and durability.

✔ *Fewer stones*

Containing over 99% beta alumina, MONOFRAX H refractory has a single-phase crystalline body which makes it exceptionally resistant to spalling. (Other refractories with several crystalline phases and a glassy matrix —each with a varying modulus of rupture—are prone to shatter and slough off into the bath). The excellent spalling resistance of MONOFRAX H material means far fewer refractory-caused defects in the glass — plus a much longer lasting superstructure.

✔ *Weighs less, therefore costs less*

Since fused cast refractories are purchased to fill a certain volume—yet are priced by weight—their density has a direct bearing on how much they cost. MONOFRAX H refractories, having a fairly open structure, are comparatively lighter and therefore offer more cubic feet of refractory per dollar.

To assist you in selecting the right materials and applying them to best advantage, we maintain a specially trained staff of engineers for consultation. They are available on short notice and without obligation. Why not avail yourself of their many years of experience? It makes good sense—requires only an inquiry to us at Perth Amboy, N. J.

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(*Continued from page* 196)

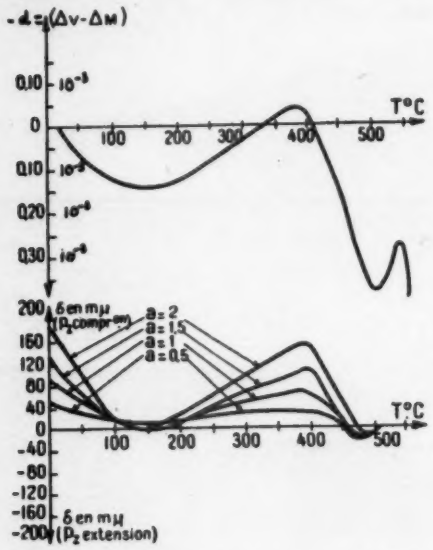


Fig. 20. Dilver P—Glass L 621 Seal. (as Fig. 19.)

strain point does not correspond to a simple translation of the expansion curve of glass to the point where it cuts the expansion curve of the metal at the annealing temperature.)

Moreover, from

$$d = \left[\left(\alpha \, {T_1 \atop T_0} \right)_{\text{Metal}} - \left(\alpha \, {T_1 \atop T_0} \right)_{\text{Glass}} \right] (T_1 - T_0)$$

the variations of strain cannot be obtained except by long and fastidious calculations which must be repeated for each glass-metal pair and each shape of sample. Some authors[9] have even formulated the effect of relaxation to evaluate the strain for a given temperature, but the calculations are equally laborious and not too precise.

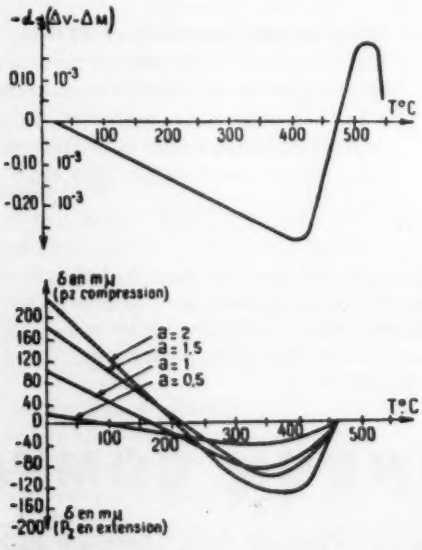


Fig. 21. Dilver O—Glass Televic 7.2.49 Seal. (as Fig. 19.)

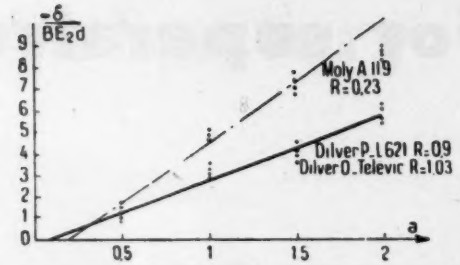


Fig. 22. Sample type B (Fig. 8). Graphic representation of δ/BE₂d (path difference : Brewster's coefficient X glass module X contraction) as a function of metal radius a. The values for R about 1 are —3(a—0.1) ; for R about .25 are —5.5(a—0.2)
δ in millimicron/kg/mm²/mm. — d in mm/mm

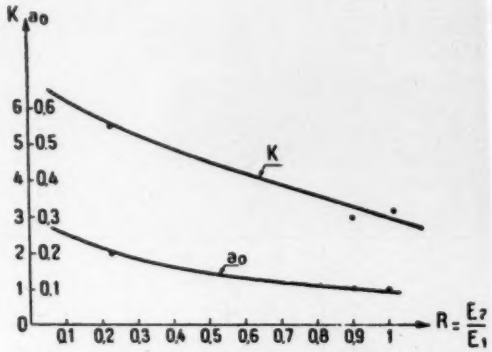


Fig. 23. Sample type B (Fig. 8). K and a_o as functions of R

Even working with sensitive dilatometers, e.g. the Chevenard instrument, the results are not too precise (elongation $\mp$ .007.10⁻³ or expansion coefficient (20—300°C.) $\mp$ 2.5.10⁻⁷).

The polarimeter, even if not too precise, such as the one used in this study, is relevant to $\mp$ 5 millimicrons, corresponding to elongations $\mp$ .0025.10⁻³ or $\alpha \, {300 \atop 20}$ $\mp$ .8.10⁻⁷.

However, differential dilatometric tests allow the precise determination of the characteristic temperatures of glasses and it will be shown what role these temperatures play in the problems of sealing aptitude and, particularly, annealing.

Polarimetric Tests.

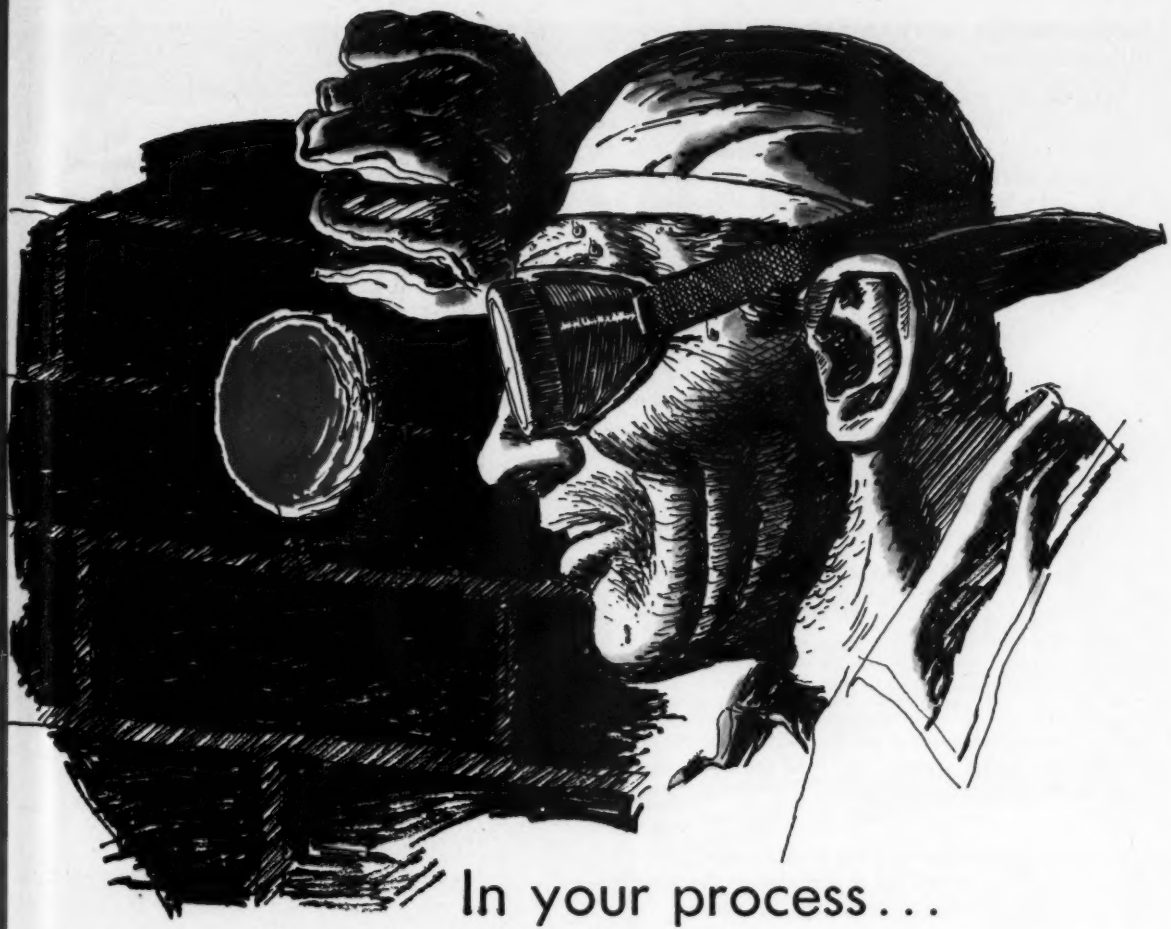
Sample Type A. For a glass-metal pair of which three structural characteristics are known (E_1, E_2, B) one obtains: (a) The coefficients of correspondence k for maximum strain and path difference as functions of $R = E_2/E_1$ and a from Fig. 16. (b) The path difference δ from a measurement on an A type sample of diameter a.

One determines the value of maximal strains by the relations:

$$(p_r)\ \max = k_r \, \delta/B$$
$$(p_\theta)\ \max = k_\theta \, \delta/B$$
$$(p_z)\ \max = k_z \, \delta/B$$

In this manner a measurement of δ permits the evaluation of the permanent strain in a glass-metal seal.

(*Continued on page* 202)



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(*Continued from page* 200)

Samples Type B. For a glass-metal pair of which one knows three structural characteristics (E_1, E_2, B) one obtains: (a) The coefficients of correspondence K for maximum strain and path difference as functions of $R = E_2/E_1$ and a from Fig. 24. (b) The path difference δ from measurement of a B type sample of radius a.

The values of maximum strain are determined by the relations:

$$(p_r)\ \max = K_r\,\delta/B$$
$$(p_\theta)\ \max = K_\theta\,\delta/B$$
$$(p_z)\ \max = K_z\,\delta/B$$

(a) The measurement of δ at room temperature on an annealed sample discloses the permanent maximum strains of the seal. (b) The knowledge of the polarimetric curve ($\delta = f(T)$) permits the determination of these strains for all temperatures at which the seal is to function. (c) If one determines on a polarimetric curve the slope of the path difference $\left(\frac{d\delta}{dT}\right)$ for a temperature T, the slope of the strain at this temperature can be evaluated as follows:

$$\frac{dp}{dT} = K\,\frac{1}{B}\,\frac{d\delta}{dT}$$

(d) Knowing the slope of the path difference for a given temperature and a sample type B of radius a_1, one may determine, thanks to the relation:

$$\delta/BE_2d = -K\,(a_1 - a_o)$$

the slope of the path difference at that temperature for a B type sample of radius a_2, if annealed at the same temperature and cooled at the same rate, as follows:

$$\frac{\left(\frac{d\delta}{dT}\right)_{a_1}}{\left(\frac{d\delta}{dT}\right)_{a_2}} = \frac{a_1 - a_o}{a_2 - a_o}$$

Figure 26 gives values of K and a_o as functions of $R = E_2/E_1$ (ratio of modules glass metal).

In the place of a slope for one point one may consider the mean slope between two temperatures. One obtains the same results provided both temperatures are in the elasticity range.

Notes. (a) The only relation which cannot be established from this study is that between the ambient temperature strains of an A or B type sample characterized by a_1 and those of an A or B type sample characterized by a_2. This relation is conditioned by the relaxation in the annealing range and will be treated in Part 2.

(b) One does well to recall that all measurements of δ are made in a plane of symmetry perpendicular to the axis, so as to eliminate end effects. Many authors[11] have studied end effects, but the present authors did not propose to consider them in an investigation stressing the description of procedures and the indication of what one can obtain from them.

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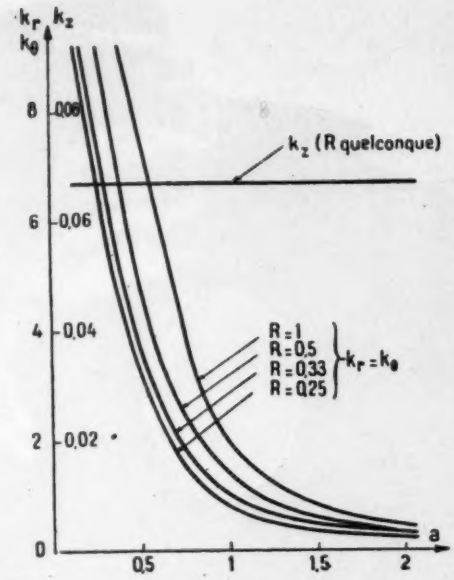

Fig. 24. Samples type B (Fig. 8). Maximum strain — path difference correspondence coefficients as functions of a (metal radius) and R (module ratio).

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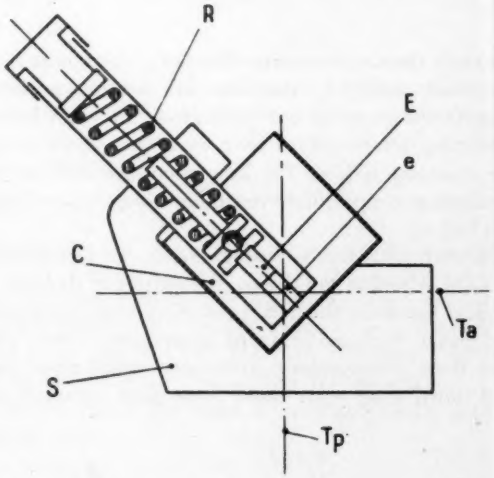

Fig. 25. Apparatus for the measurement of the Brewster coefficient

Ta Trace of the analyzer plane
Tp Trace of the polarizer plane
S Support
E Known } samples
e Unknown }
R Compression Equipment
C Cuvette Containing Index Liquid

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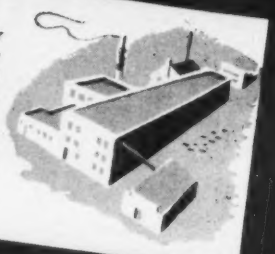

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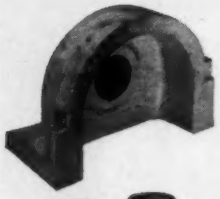

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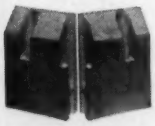

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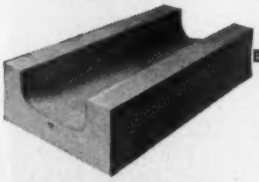

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With a program expected to materially increase the manufacturing breadth and the industry-service scope of Wyandotte Chemicals Corporation, Robert B. Semple, President, has announced the first step in an expansion that, it is anticipated, will accelerate the rate of growth Wyandotte has enjoyed in the last decade when its sales volume has more than doubled.

According to Mr. Semple's announcement, the program will include significant growth in Wyandotte research and development activities, with emphasis not only on the development of new products, but also on assistance to industrial chemical users of the corporation's products.

The program will involve the three chemical manufacturing and compounding plants located in Wyandotte, a suburban community on the Detroit River, eleven miles south-west of Detroit; the limestone quarries at Alpena, Michigan; the clay operations at Blue Mountain, Mississippi; and the compounding plant at Los Angeles, California.

The activity now projected, Mr. Semple said, will not only increase the output of the three basics—chlorine, soda ash, and caustic soda—but will provide processing facilities which will permit the company to upgrade the present line of products, with emphasis in the organic field.

Ground has already been broken in Wyandotte for a new research pilot plant and the Wyandotte Research Center. The Research Center will be approximately a city block and a half long, and a half block wide. It will be next to the company's Administration Building on Wyandotte's main thoroughfare. Occupancy of the building, which will house all the scientific and technical groups under the supervision of Dr. Thomas H. Vaughn, Vice President-Research and Development, is scheduled for mid-1952.

Included in the Center will be special areas devoted to exploration in such fields as radioactive tracers, nucleonics, electronics, organic and inorganic chemistry, sanitation and germicides, electroplating, physics, and the entire field of commercial cleaning served by the company's dishwashing compounds, laundry detergents, and metal and industrial cleaners.

ATOMIC STANDARDS OF LENGTH NOW AVAILABLE

The availability to science and industry of an ultimate standard of length has been announced by the National Bureau of Standards and the Atomic Energy Commission. The standards consist of spectroscopic lamps containing a single pure isotope of mercury. These lamps enable any research organization which has the auxiliary optical equipment to have for the first time an ultimate primary standard of length of its own laboratories.

Distribution of the lamps will be handled by the National Bureau of Standards. They will be available to qualified government, industrial, and educational laboratories, both in this country and abroad, engaged in precision length measurements and related research. All requests for information and applications should be addressed to the Coordinator of Atomic Energy Commission Projects at the National Bureau of Standards, Washington 25, D. C.

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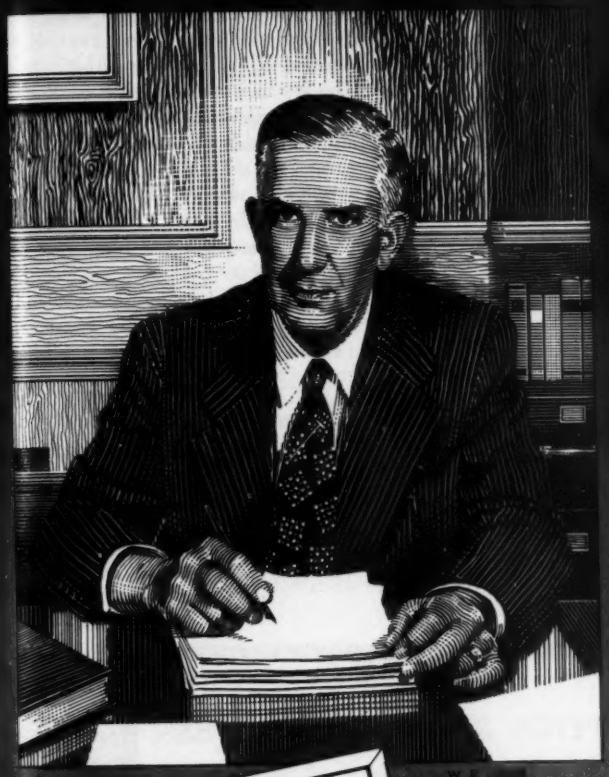

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OUTSTANDING PEMCO PRODUCTS IN USE THE WORLD OVER

A.C.S. MEETING . . .
(*Continued from page* 175)

lurgy, can become equally so for glass technology.

The development of low dielectric-constant borosilicate glasses is the subject of a paper to be presented by J. H. Plummer of Glass Fibers, Inc.

A paper by R. C. Turnbull and W. G. Lawrence, New York State College of Ceramics, based on a study of a series of glasses in the system Na_2O-SiO_2-TiO_2, will describe the role of titania in silica glasses.

In another paper, R. C. Farnham, in collaboration with W. G. Lawrence, presents the effect of minor additions of oxides on the surface tension of a soda-lime-silica glass.

F. V. Tooley, Professor of Glass Technology at the University of Illinois and Secretary of the Glass Division, will discuss the effect of preparation conditions on the tensile strength of soda-lime-silica glass rods. Dr. Tooley submits that of the utmost importance is the careful control of specimen preparation conditions in strength studies.

Over a period of time, several papers have appeared in THE GLASS INDUSTRY on the subject of the adherence of glass to metals. Investigation of the adherence of glass to metals and alloys has been continued at West Virginia University. W. A. Koehler and R. C. Dartnel will present some of their latest findings on the subject to the members of the Glass Division of the A.C.S.

Other papers scheduled for the Chicago meeting are: magnetism and the structure of glass by P. W. Selwood, Northwestern University; S. W. Barber's paper on the polarization of ions and temperature dependence of viscosity and electrical resistivity of soda-silica glass; and a paper by J. H. Schulman, R. J. Ginther, C. C. Klick, and E. W. Claffy of the Naval Research Laboratory which deals with the effect of high-energy radiation on the absorption and luminescence of glasses and crystals.

On the lighter side of the Meeting, a good program of entertainment has been provided for the attending members. The Chicago Association of Commerce Glee Club and Miss Nancy Carr, radio artist, will provide entertainment at the General Reception timed for Sunday evening, April 22. The general banquet is scheduled for Monday evening, the 23rd, with a floor show and dancing to follow in the Grand Ballroom of The Palmer House.

An interesting program for the ladies will be directed by Miss Josephine Mutter. Included in the plans are radio tours, a luncheon and style show, a tea, an interesting plant trip, and a book review presentation.

The Camera Club will hold its twelfth annual exhibit during the Chicago Meeting. An interesting addition to the Salon this year will be a special exhibit of photography by the wives of members of the Society.

BALL BROTHERS NAMES CONTROLLER

F. A. Schlossstein of St. Louis, contract manager and supervisor of audit engagements for Price, Waterhouse & Company, has accepted the post of controller for Ball Brothers Company.

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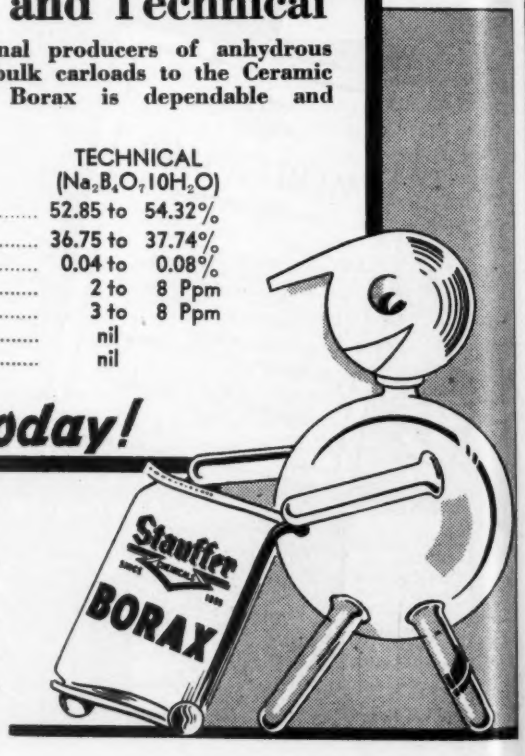
Iron as Fe	30 to 35 Ppm	2 to 8 Ppm
Arsenic as As_2O_3	20 to 40 Ppm	3 to 8 Ppm
Sulphates as Na_2SO_4	0.3 to 0.4%	nil
Carbonates as Na_2CO_3	nil	nil



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NEW ANNEALING LEHR . . .
(*Continued from page* 177)

Figure 3. Location of the thermocouple readings is shown in Figure 4.

This transvertical lehr provides an opportunity for testing a new theory regarding annealing processes as applied to glass. If glass is processed through a continuous annealing lehr in such a manner that the glass is always in motion, as would be the case in any continuous belt type lehr, the glass is continuously subjected to varying temperatures along the curve. Therefore the glass does not have an opportunity to equalize at any given temperature. If this is true, is seems reasonable to believe that there would be a temperature gradient between the interior and the exterior of the ware. A continuous state of stress should therefore result. In the transvertical lehr, the movements are intermittent and the ware has an opportunity to soak at each successive drop in temperature. This should provide an opportunity for equalizing of temperatures and, therefore, maximum stress relief. Limitations of time and precise measurement facilities have not permitted the experimental verification of this theory by stress analysis methods, but we have observed an extremely high efficiency of annealing in the transvertical lehr, as measured by the fact that our rejections after annealing have been extremely low.

Fits Into Standard Production Line

An idea of how the transvertical lehr has fitted into our production line setup is provided by Figure 5, which shows a schematic layout of the tank, press machines, fire polishers, and lehrs. To show the comparative space requirements, we have also included in this schematic drawing, a representation of the two conventional belt type lehrs on either side of the transvertical lehr.

The operation flow is standard for pressed ware production at plants such as The Jeannette Glass Company. This ware includes a wide variety of tumblers, stemware, lamp components, ash trays, dishes, novelties, and other pressed products.

We have found the operation and maintenance of this new lehr to be quite simple and inexpensive. The power drive is supplied entirely by a single 1 horsepower motor, located at the base of the lehr for ready accessibility. Speed control is obtained through simple reduction gears. Automatic power-shutoff by means of an overload safety clutch is incorporated in the drive to prevent damage to the mechanism in the event that excessive torque is applied. However, we have found that the designed tray loading of 10 lb. per sq. ft. of tray area has been ample to meet requirements of most of our jobs.

The construction of the transvertical lehr is similar to that of most modern lehrs. It is composed of a frame of structural shapes with a casing of 3/16 in. or heavier plate. Components are bolted or welded together, as required. The lehr is fully insulated to provide worker comfort as well as high thermal efficiency. Both charge and discharge ends of the lehr are equipped with hand operated roll-up curtains to provide a maximum effective discharge height of 18 inches.

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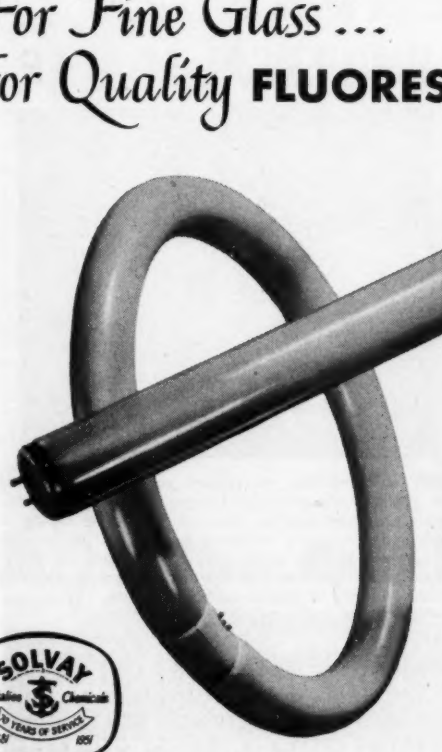

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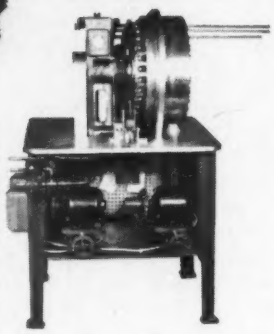

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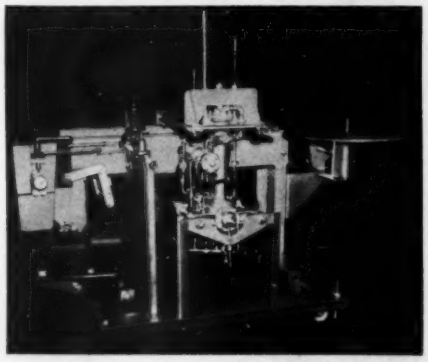
Jeannette Glass Company over the past nine months during which the lehr has been in continuous operation. Apparently, we are not the only glass plant where floor space is at a premium. We are still exploring the possible applications of the transvertical lehr and are finding new uses for it in the various production jobs as they are received. It is our understanding that the design of this lehr is undergoing further development in the engineering department of the manufacturer with the view to expanding its field of application.

RESEARCH DIGEST . . .
(*Continued from page* 187)

mission. Lithium borate glasses were slightly better and potassium borate glasses were a little worse than corresponding sodium borate glasses, but nothing absolute can be claimed for these results owing to unavoidable impurities even in the purest available raw materials.

It was shown that small percentages of iodine in a sodium borate glass caused a marked absorption of 2537A. radiation. Sodium borate glasses containing a small percentage of sodium sulphate, melted under reducing conditions, may be colorless, blue, or yellow, depending upon the Na_2O content, the ultraviolet transmission being reduced in all cases by the presence of sulphur. Inclusion of 0.5 per cent ZnO or CdO in a sodium borate suppressed the sulphur blue color and increased the ultraviolet transmission; a similar inclusion of CaO, MgO, or BeO failed to suppress the blue color although the addition of the BeO improved the 2537A. transmission.

GLAPAT
UNIVERSAL LOADER



• Built to meet the specialized requirements of high-speed glass production, the Glapat universal loader is a compact, unitized machine featuring accurate timing and smooth, steady action without vibration. It is widely used for both blown and pressed ware, and for loading decorating lehrs. Sturdy Glapat construction makes this machine a money-saving investment for you.

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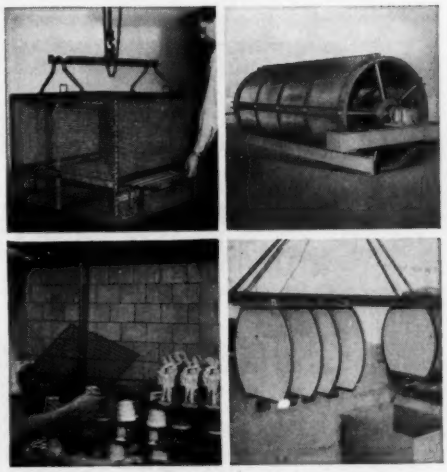

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Submit your own blueprints for quotation, or merely give us the details of the process for which the assembly must be designed. Our trained engineers and metalworkers will do the rest.

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Standard plungers in all sizes from MG1 to MG10. Easily machined and polished to a mirror finish.

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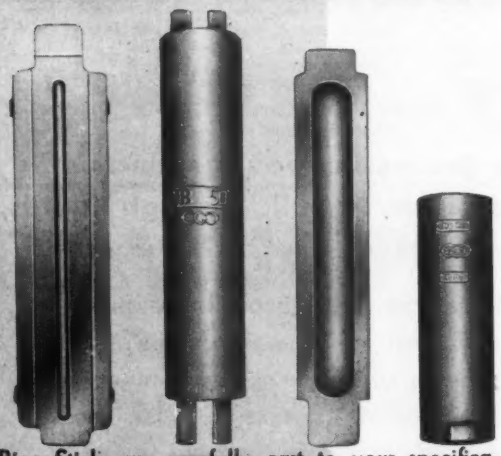

Ring Sticks are carefully cast to your specifications from your own patterns. Readily machinable.

BAR STOCK

Round bars in standard 14 inch lengths. 1/2 inch diameter to 5 inch diameter by 1/4 inch increments.

ALL GUNITE castings are made of Gunite Metal suitably alloyed to provide the ideal glass house material. Gunite Metal is easily machined and readily polished to a mirror finish. Gunite Metal has maximum resistance to heat checking under the severe conditions imposed by glass making operations. You'll get superior service from GUNITE.

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ROCKFORD GUNITE ILLINOIS

A.C.S. SECTION MEETINGS

The New York Metropolitan Section of the American Ceramic Society held its third meeting of the year at which were featured talks by H. W. Leverenz of the RCA Laboratories and Dr. E. Both of the United States Signal Corps laboratories at Fort Monmouth, New Jersey.

Mr. Leverenz described the development of luminescent solids and the great care which must be taken in the preparation of these materials. Dr. Both spoke on Ferrites, explaining the advantages and disadvantages of this newly developed ceramic.

The Section's fourth meeting of the year featured W. W. Winship of the Winship Silica Products Company and S. B. Seeley of the Joseph Dixon Crucible Company. Mr. Winship described the history, manufacture, and uses of fused silica products, stressing their extremely low expansion characteristics and low loss electrical properties. Mr. Seeley gave an entertaining talk on "Unit Operations in Processing Graphite Products".

The Tennessee Valley Section of the Society featured two technical sessions, a banquet, and plant trips for its most recent meeting. The technical program included a "Symposium on Titanium Steel and Enamel" by Messrs. J. B. Simons and Gibbs of Westinghouse Electric Corporation, a talk on the latest developments in the "Manufacture of Silica Refractories" by J. H. Varner of Harbison-Walker Refractories Company, and a paper on new research in the field of "Concrete" by Dr. Locke White of Southern Research Institute.

The Pittsburgh Section held its annual Ladies Night which consisted of a dinner-dance at the Palace Inn in the Beaver Valley near New Brighton, Pa.

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FOR SALE OR LEASE, more than 500,000,000 tons of silica sand, rock, and clay in Huntingdon County, Pennsylvania, along the Juniata River. Ralph A. Smith, Tyrone, Pennsylvania.

INCREASE IN RAIL FREIGHT RATES

The Interstate Commerce Commission has handed down its decision in Docket Ex Parte 175 which was the rail carriers' proposal for an interim increase of 6 per cent in freight rates in all territories pending final decision of the ICC on the rail lines' application for increased rates.

The order issued, effective April 4, 1951, gives the rail carriers the privilege to increase the rates on carload and less than carload freight, with a few exceptions, by 4 per cent in Official Classification Territory, 2 per cent in Southern Classification Territory, and 2 per cent in Western Classification Territory. The Inter-territorial Rates between those territories will be increased 2 per cent.

There are a few exceptions to the general rule where specific increases in cents per hundred pounds are to become effective instead of the percentage increase. There is to be no increase in Demurrage Charges. The increase will apply on COD Collection Charges, and also applies on both Class and Commodity Rates in carloads and less to the extent above enumerated. The same increases are provided for Freight Forwarders that are provided for the rail lines.

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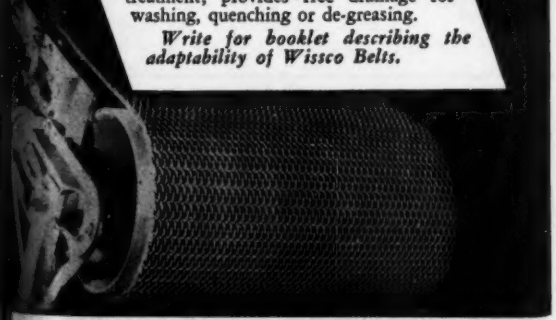
Where processing applications call for stand-up performance under punishment —there's nothing to equal long-wearing Wissco Metal Processing Belts.

Wissco Belts are specially engineered for high resistance to abrasion, corrosion and temperature extremes. Their patented mesh construction permits free circulation of air for more uniform heat treatment; provides free drainage for washing, quenching or de-greasing.

Write for booklet describing the adaptability of Wissco Belts.



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